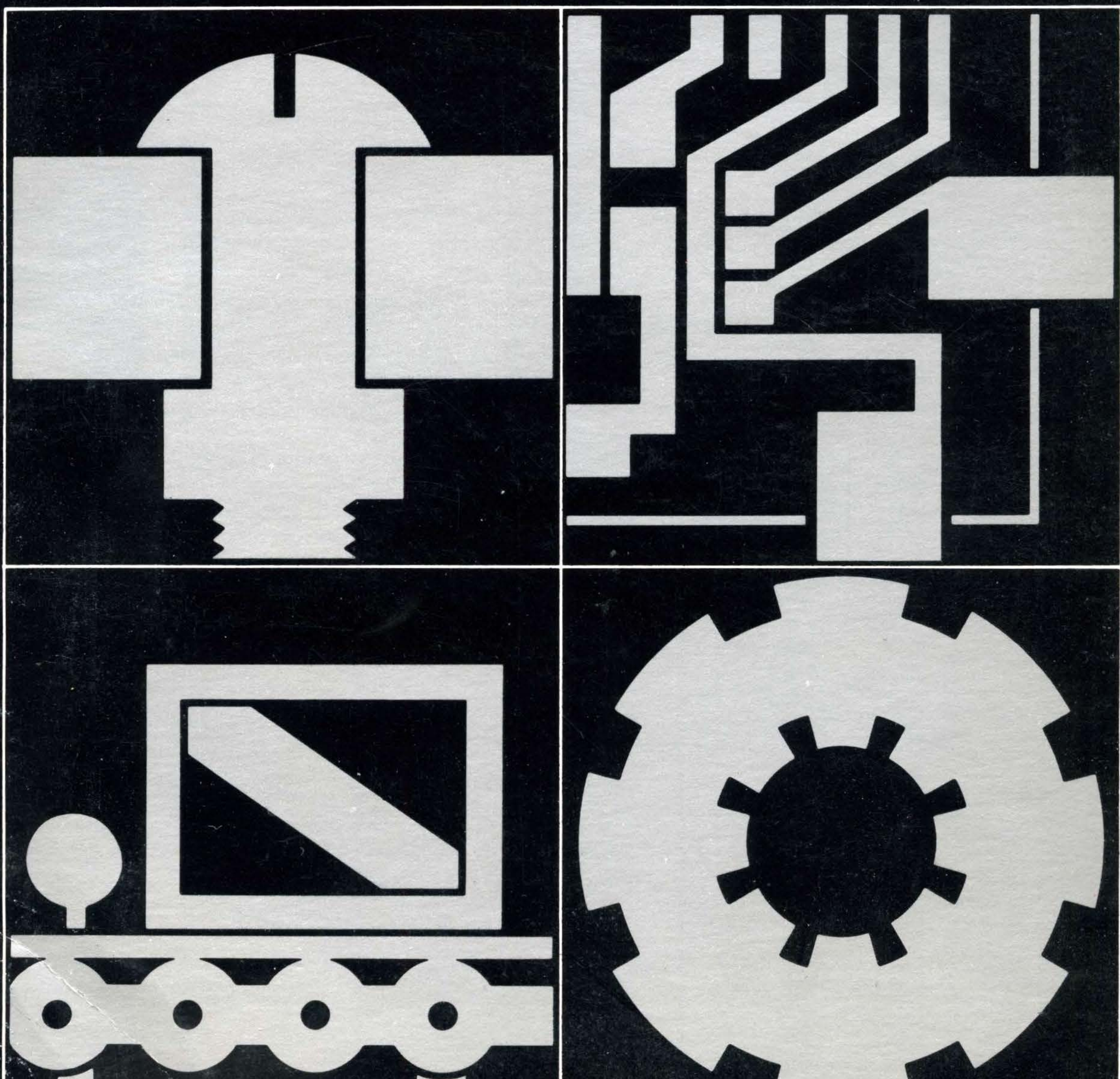
IBM

Communications Oriented Production Information and Control System

Volume IV

Chapter 5 Inventory Management



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Communications Oriented Production Information and Control System

Volume IV

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First Edition (March 1972)

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Foreword

COPICS (Communications Oriented Production Information and Control System) is a series of concepts that outline an approach to an integrated computer-based manufacturing control system. The concepts deal with problems common to most companies, from a forecast of customer orders, through development of the master production schedule, to production and shipment of the product. COPICS is involved, therefore, with allocation and control of most of the major resources of a company – plant, equipment, manpower, and materials.

COPICS evolved from the approach to manufacturing applications presented in the IBM publication *The Production Information and Control System* (GE20-0280). In COPICS those applications are defined from a communications point of view and have been expanded in scope.

The twelve COPICS chapters provide management with a guide for development of a dynamic online manufacturing control system that is terminal and communications oriented and event responsive. The chapters present the system's concepts in a manner designed to help develop a system that can truly respond to the requirements of all levels of operating personnel and management. Little knowledge of computers is assumed, although some prior exposure to computer concepts and familiarity with such terms as "program", "files", etc., is helpful. Emphasis is on what the problems are and *why* their solution is valuable. How specific problems are solved is discussed only at that level of detail required to assure managers that the solution is feasible. The computer is not, itself, the system, but is, rather, a tool to be used by the manager.

The COPICS concepts are oriented to production and related manufacturing applications. They are not concerned directly with other major areas, such as finance, marketing, and personnel, although the COPICS approach collects data that will be helpful to these areas.

Throughout the COPICS publications, distinction is made between a given COPICS concept, the corresponding chapter, and the corresponding plant department by the use of small capital letters, italics, and initial capital letters, respectively. For example, reference may be made to the COPICS concept PURCHASING AND RECEIVING, or to material in *Chapter 10, Purchasing and Receiving*, or to the plant departments called Purchasing and Receiving.

The complete system is presented in eight volumes containing, in all, 17 sections. The Management Overview section is also available as a separate publication, G320-1230. The contents and IBM order numbers of the eight volumes are as follows:

Volume I	G320-1974	Management Overview, System Requirements, Index, Glossary
Volume II	G320-1975	Chapter 1 Engineering and Production Data Control
		Chapter 2 Customer Order Servicing
Volume III	G320-1976	Chapter 3 Forecasting
		Chapter 4 Master Production Schedule Planning
Volume IV	G320-1977	Chapter 5 Inventory Management
Volume V	G320-1978	Chapter 6 Manufacturing Activity Planning
		Chapter 7 Order Release
Volume VI	G320-1979	Chapter 8 Plant Monitoring and Control
		Chapter 9 Plant Maintenance
Volume VII	G320-1980	Chapter 10 Purchasing and Receiving
		Chapter 11 Stores Control
		Chapter 12 Cost Planning and Control
Volume VIII	G320-1981	System Data Base

To obtain the complete set of eight volumes please order the IBM Bill of Forms number GBOF-4115.

Contents

Introduction

Among the COPICS concepts, INVENTORY MANAGEMENT has a special place. It can be considered the keystone of the overall system, as its outputs form the basis for all subsequent production planning and all manufacturing, as well as procurement, activity.

The primary function of INVENTORY MANAGEMENT is to generate information on which inventory order action will be based. The system is designed to determine:

- Inventory items that should be ordered, and in what quantity
- The timing of each order release, and order due dates
- Changes in quantity or due date (rescheduling) of orders already released
- Orders previously released that should be canceled

Changes in customer demand, new product introductions, engineering changes, excessive scrap, etc., require a system that can react quickly, minimize shortages, and maintain a minimum investment in inventory.

The techniques employed by INVENTORY MANAGEMENT and outlined in this chapter are intended to ensure that the following objectives are met:

- Improved customer service through a reduction in the number of late customer deliveries, and thus an improved competitive position
- Reduced investment in all types of inventory, that is, finished products, components, work-in-process, raw materials, maintenance parts, tools
- Improved timing in the delivery of component parts to stores, thus minimizing assembly shortages and expediting costs

Need for management control

Improved management of inventory can release money for use in other areas of the business. Inventory, therefore, should be considered in the same light as any other investment; a profitable return should be expected. A reduction in inventory not only releases money for investment in other areas, but also reduces costs. Considering such things as cost of money, as well as insurance, taxes, storage costs, etc., it is quite common for the cost of carrying inventory to exceed 20% of its average annual level.

In many companies, management has little actual control over the level of this investment. Quite often, inventories tend to grow until some kind of crash program is initiated to reduce them. Investment in inventory is usually not planned, it just happens.

Excess inventory on some items and stockouts on others usually result from a number of operating-level decisions by inventory control personnel. These individuals are subject to many pressures. If one of them makes a decision that results in a severe shortage, he will tend to stock more inventory in the future, in an effort to avoid the recurrence of the unpleasant situation. He knows that material shortages will hurt his relations with the production organization, whereas a high inventory can be "explained" to top management. A reduction of inventory levels is usually effected by reducing order quantities, carrying less safety stock, or scheduling purchased items to arrive a little later. If these changes are not implemented correctly, severe shop disruptions are likely to occur and manufacturing costs will increase.

The INVENTORY MANAGEMENT system enables the responsible executive to exercise direct control over implementation of inventory policy, and to know in advance the likely levels of both inventory investment and customer delivery service. For this reason, it can be one of the most valuable, and profitable, applications.

Inventories in a manufacturing company

From an investment standpoint, the ideal situation would be to carry no inventory. From an operating standpoint, however, inventories are a necessity, for a number of reasons. The manufacturing lead time alone accounts for an investment in work-in-process. Other types of inventory are also required:

- Finished product inventories are maintained in anticipation of demand, and to absorb the differences between forecast and actual customer orders.
- Inventories of semifinished component parts and subassemblies are maintained in order to reduce the quoted delivery time for the end product.
- Inventory is also carried as a protection against possible late delivery. To avoid shortages, delivery may be specified for some time before it is actually required. If delivery is not late, it will raise inventory because the stock must be carried until it is actually used.
- The order quantity for a manufactured item may exceed requirements, so as to spread the cost of setup over many units. Excess quantities are also ordered to take advantage of supplier volume discounts and to reduce purchasing, receiving, and materials handling expenses.

- In many industries the objective is to maintain a constant rate of production despite seasonal fluctuations in customer demand. During periods of low demand, inventory is created in anticipation of higher demand later in the cycle.

For these and other reasons, inventories are necessary; however, the level of inventory can vary within a significant range. This chapter presents a system that helps reduce inventory to the minimum level consistent with the stated objectives of management. It provides the capability to resolve the conflicting requirements of Sales, Production, and Finance.

The procedures outlined in this chapter apply to almost all types of inventory, as shown in Figure 1. The control of work-in-process inventory, however, is addressed in *Chapter 6, Manufacturing Activity Planning.* Work-in-process is defined as all raw material, components, and subassemblies released to the shop floor as part of a shop order.

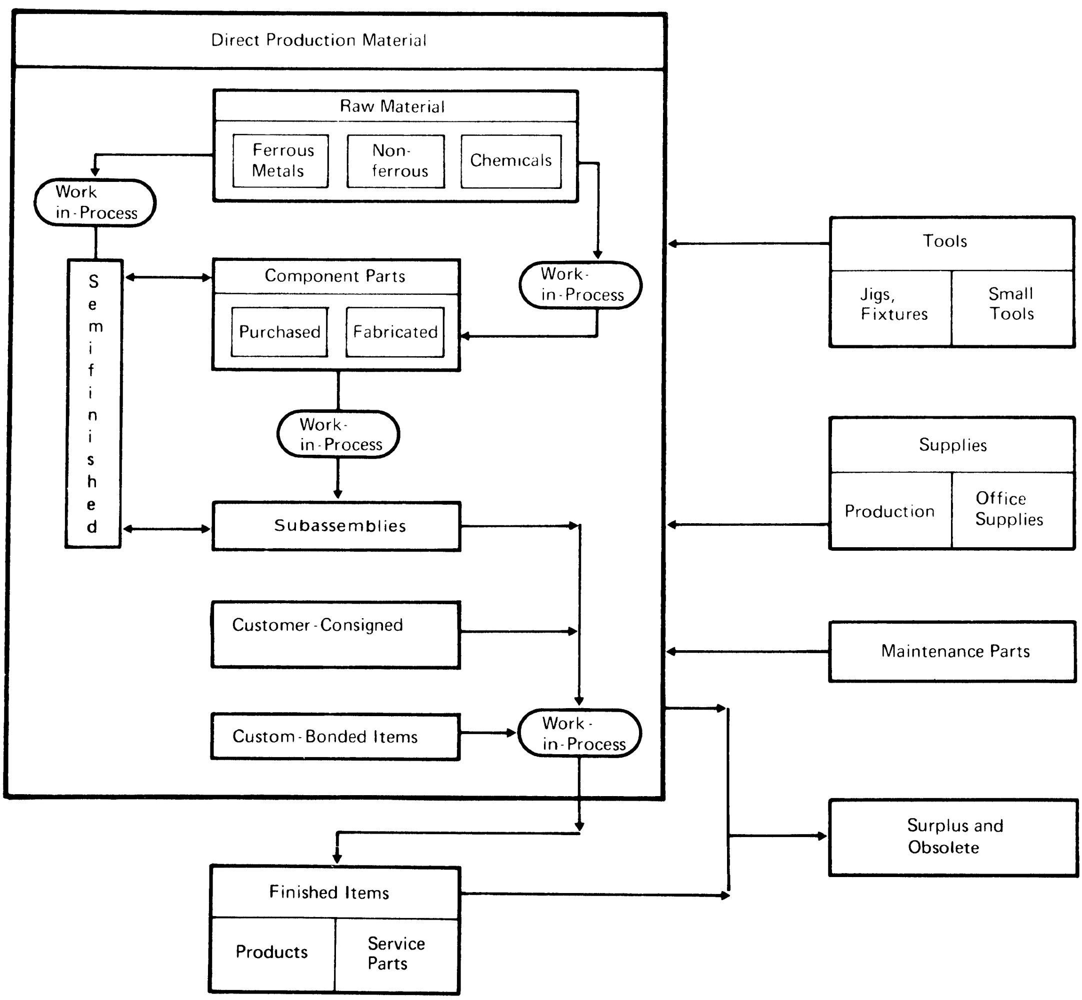


Figure 1. The control techniques presented in this chapter apply to most classes of inventory

Systems providing input to Inventory Management

INVENTORY MANAGEMENT is dependent on other application areas for timely, accurate input (see Figure 2). These areas and their input can be summarized as follows:

- ENGINEERING AND PRODUCTION DATA CONTROL maintains bills of material used to explode the requirements of the master production schedule, and the changes made to this schedule. The effectivity of engineering changes also directly affects INVENTORY MANAGEMENT.
- CUSTOMER ORDER SERVICING supplies the actual product demand. When customer orders are entered at a terminal, *allocations* are automatically made against the product on-hand balance or the production schedule. An allocation can be thought of as a reservation against available inventory.

  Order entry also creates requisitions for finished product shipments. These requisitions are transmitted automatically to the shipping department or warehouse.
- FORECASTING uses the demand supplied by CUSTOMER ORDER SERVICING to develop a projection of sales by time period. Management modifies the forecast to reflect known changes, such as promotions, market expansion, competitive activity, etc. A forecast is developed for each item sold as a finished product (or for product families and variable features within these), including service parts. There may be separate forecasts for each branch or field warehouse. The forecasts are input to MASTER PRODUCTION SCHEDULE PLANNING.
- MASTER PRODUCTION SCHEDULE PLANNING handles changes to the requirements for finished products. A master production schedule is developed to cover these finished product requirements. Since the forecast demand may be seasonal, the planning procedure provides aids that help level the load placed on the plant.

The forecast may exceed the planned capacity levels of the plant. Therefore, the schedules are compared against available and planned resources. The result of MASTER PRODUCTION SCHEDULE PLANNING is a realistic production schedule. The new schedule is compared with the previous schedule, and any difference, called "net change", is input to MATERIAL REQUIREMENTS PLANNING.

The system develops a final assembly schedule based on customer delivery requests, assembly capacity, and availability of material. Where requirements of the final assembly schedule exceed those foreseen by MATERIAL REQUIREMENTS PLANNING, the master production schedule may have to be revised accordingly, and reprocessed. The system will then indicate which orders must be rescheduled and expedited.

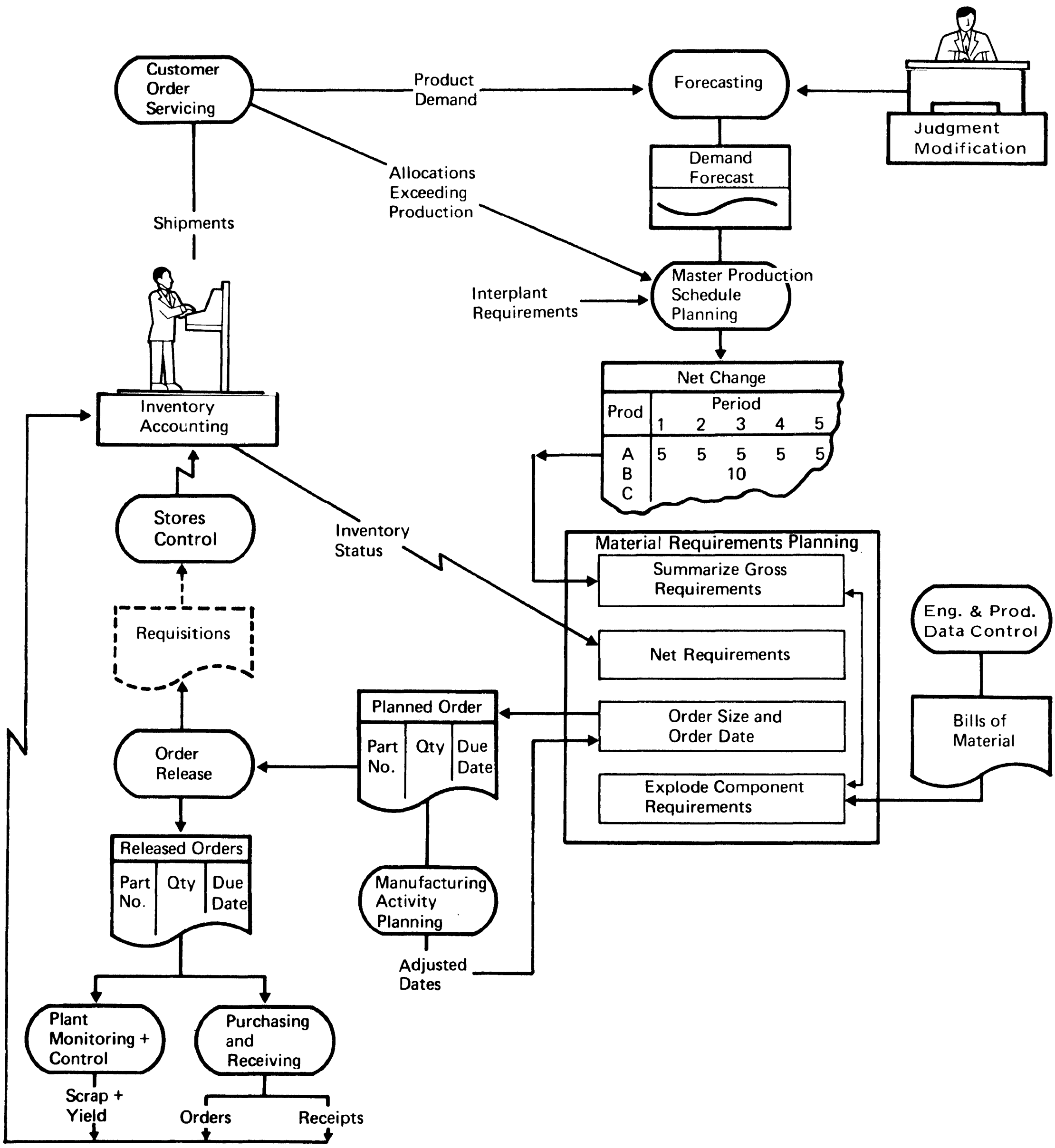


Figure 2. The relationship of INVENTORY MANAGEMENT with other areas of COPICS

Inventory Management functions

Addressed in this chapter are two broad functions encompassed by INVENTORY MANAGEMENT:

- INVENTORY ACCOUNTING
- INVENTORY PLANNING AND CONTROL

INVENTORY ACCOUNTING concerns the administrative, or bookkeeping, aspect of inventory control. This function covers the entry, auditing, control, and processing of inventory transactions. Included are transaction history and audit trails, as well as the gathering of transaction data from remote locations. Physical control over stock, and inventory counting procedures are discussed, as are ways in which terminal entry of transactions improves accuracy and ensures system integrity.

INVENTORY PLANNING AND CONTROL consists of planning procedures and techniques that lead to inventory order action. The nature of demand is discussed, and the concept of independent/dependent demand is explained. It is shown how statistical inventory control and material requirements planning methods can be combined into one integrated inventory planning system that accommodates all inventory items. The technique of "net change" in material requirements planning is applied, to permit a transition from batch processing to an online mode of operation.

The individual major functions of INVENTORY MANAGEMENT are outlined in Figure 3:

- *Determining gross requirements.* In order to satisfy the master production schedule, the requirements for all material are determined at all levels, from major assemblies to raw material. This includes the processing of changes to the forecast, revisions to customer orders and engineering changes, etc. All these changes are processed in a "net change" mode. Under "net change", the effect of changes can be determined immediately without waiting for a weekly or monthly batch computer run.
- *Determining net requirements.* The gross requirements, just derived, are normally in excess of what is really needed. This is because of on-hand inventory, including safety stock, released shop orders, and consideration of stock already allocated. These are all considered in determining the net requirements, which, in turn, are used in planning production and purchase orders.
- *Determining order size.* The quantity for planned orders could be the exact net requirements. Although this would minimize inventory carrying costs, the associated acquisition costs could be inflated. The system balances these costs by determining an economical order quantity for each planned order.

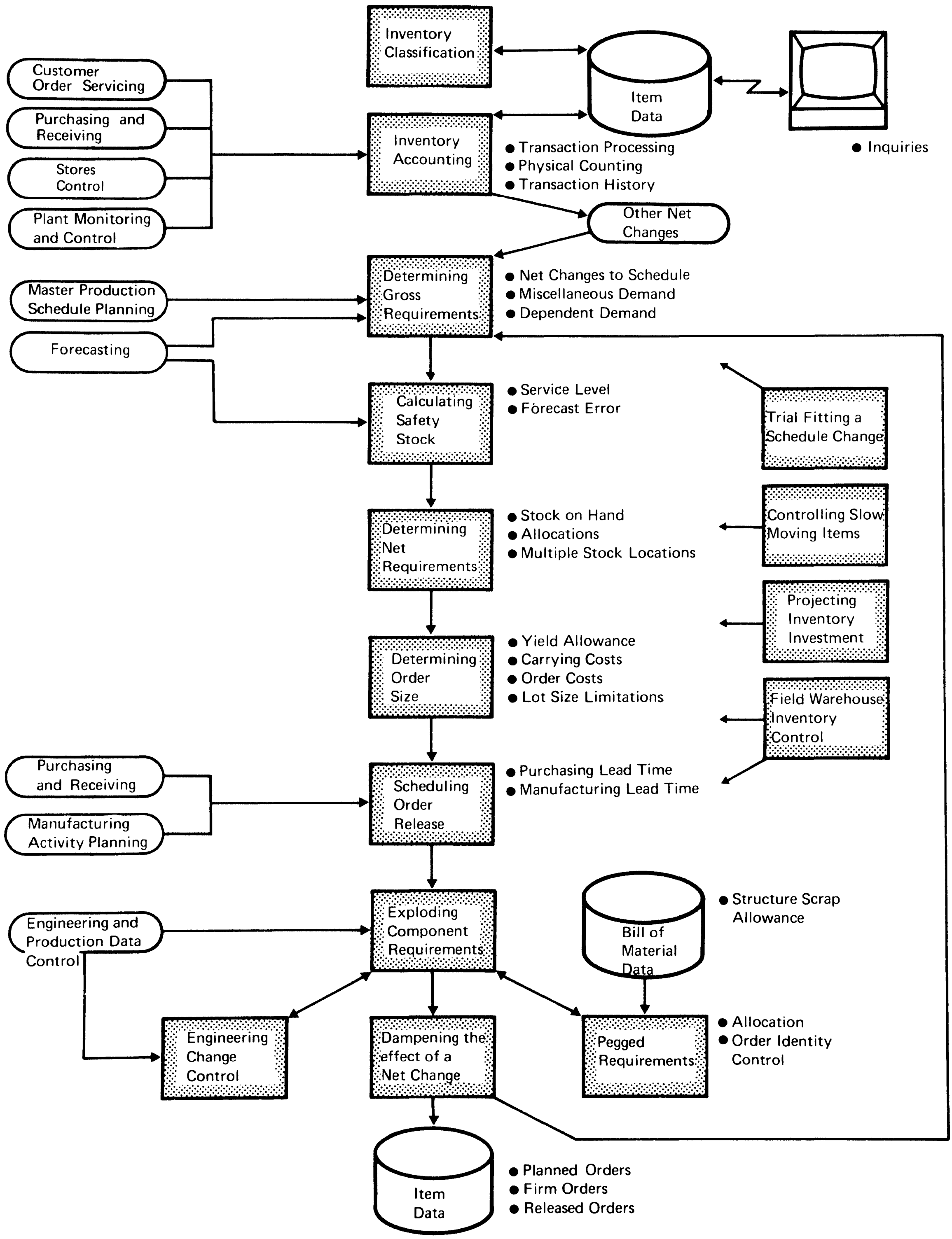


Figure 3. The basic functions addressed in INVENTORY MANAGEMENT. Functions connected to symbols representing other areas of the system are explained in more detail in the appropriate chapter. For example, the calculation of manufacturing lead time is discussed in detail in ***Chapter 6, Manufacturing Activity Planning***

- *Scheduling order release.* The planned release date of an order is based on the normal manufacturing or purchasing lead time – the time to "acquire" the item. Components, subassemblies, and raw materials are normally required to be available when a planned order is scheduled to start. The system "offsets" or back-schedules these planned orders to determine the shop release date.
- *Exploding component requirements.* Requirements for components and raw material are determined by the planned order quantity of subassemblies, assemblies, and end items. Assembly order quantity is extended or "exploded" for all items on the list of required components or bill of material. Net requirements are determined and component orders are planned. This process is repeated for each level in the bill of material, that is, each assembly through the raw material level.

A related section entitled "Inventory Planning and Control" discusses additional significant features of the system:

"pegging" requirements

"Pegging" requirements involves allocating available and planned inventory to planned orders or requirements. The system maintains pegging connections that indicate the source of requirements. Pegging is used for several purposes, for example:

- To trace the effect on customer orders of an expected or actual component delay
- To help implement engineering changes – for instance, on serial-numbered products
- To maintain identity of items being assembled into a specific finished product (see "Configuration Control" in *Chapter 1, Engineering and Production Data Control*)

trial fitting of proposed schedule changes

Trial fitting of proposed schedule changes is a feature whereby proposed changes to the master production schedule may be processed using "net change" techniques to determine their effect. The system will highlight materials to be expedited or delayed and the probable effect on the planned delivery dates.

In addition to the main functions of INVENTORY MANAGEMENT, this chapter discusses field warehouse inventory control, special considerations of material requirements planning in a multiplant environment, projecting inventory investment, dampening the effects of change, and the proper use of the system.

Systems dependent on Inventory Management

The following application areas act on the planned order information supplied by INVENTORY MANAGEMENT (Figure 2):

- MANUFACTURING ACTIVITY PLANNING performs an analysis of the load that orders generated by MATERIAL REQUIREMENTS PLANNING place on production facilities. Orders not yet released to the shop floor or to the supplier are called "planned orders". The release date of planned orders may be modified in order to level the planned load on the plant. If, because of overload, it is impossible to complete all orders on time, the system recommends delays of low-priority orders and passes the revised dates back to MATERIAL REQUIREMENTS PLANNING so that associated orders can also be revised.
- ORDER RELEASE constantly reviews the scheduled release date for planned orders. At the time of release it prepares requisitions, shop paperwork, and action notices. The status of the order is changed from "planned" to "released". For purchased items, a purchase requisition is created via PURCHASING's Action File.* For manufactured items, requisitions for component parts and raw materials are set up in a STORES CONTROL Action File.
- PURCHASING generates requisitions for purchased material. The placing of the purchase order is confirmed by entering the vendor number selected and any *date and quantity changes* on a terminal display of the purchase requisition. The status of the released order is updated to indicate that it has been released to a supplier.
- STORES CONTROL fills requisitions for raw materials and for components of assembly orders. The transactions are transmitted to INVENTORY ACCOUNTING for updating of inventory records.
- PLANT MONITORING AND CONTROL transfers information concerning completion of shop orders, along with intermittent scrap and yield data, to INVENTORY ACCOUNTING. As a shop order progresses through the shop, scrap is reported as a by-product of terminal-oriented labor reporting, or inspectors may make separate terminal entries of scrap and rework. The shop order quantity is subsequently reduced by the amount reported as scrapped.

  If any transaction processed by INVENTORY ACCOUNTING results in a net requirements change, the system starts a "net change" requirements planning process and replans all affected records.

* The Action File concept is explained in *System Data Base*. It involves communications notices stored in the system's memory. The notices are arranged in priority sequence. Each notice represents a request for action and is directed to a particular area. As the required action is taken, it is reported via terminal and the respective Action File notice is removed from the file. For example, when a stores requisition is reported filled, the picking request is removed from the STORES CONTROL Action File.

Inventory Accounting

INVENTORY ACCOUNTING comprises the reporting and bookkeeping functions of INVENTORY MANAGEMENT. It covers the gathering of inventory transaction data and its auditing, control, and entry into the system for processing. INVENTORY ACCOUNTING maintains the integrity and accuracy of the inventory record on which INVENTORY PLANNING AND CONTROL depends.

Unless strict control over the reporting of inventory transactions is established and maintained, the entire system will prove ineffective. An inaccurate, incomplete, or out-of-date inventory record cannot form a basis for correct planning and order action. If the system is to generate valid outputs, the flow of *data* must accurately represent the flow of *materials* through the actual process.

INVENTORY MANAGEMENT is designed to minimize inventory investment. When excessive safety stocks, early delivery into stores, and other "cushions" are eliminated from inventories, record errors become more critical.

Furthermore, it is desirable that the system be accurate enough to build confidence in its reliability. Once this is accomplished, people using the system will accept both the inventory records and the action recommendations that are based on them. They will then refrain from additional checking, verification, and double-guessing of the figures generated by the system.

INVENTORY ACCOUNTING performs essentially simple, mundane, but vital functions. It is as important to the success of INVENTORY MANAGEMENT as its planning procedures and advanced control techniques.

Control over inventory reporting is established by:

- Making sure unauthorized stock issues do not occur. This normally means having "closed stores" (see *Chapter 11, Stores Control*).
- Keeping track of material in transit and making sure it is properly identified and stored in the designated location (see again *Chapter 11*).
- Making sure that all transactions are processed, that they are processed accurately, and that the data is entered correctly at the point of origin. The techniques outlined help accomplish these objectives through automatic auditing, authorization procedures, immediate notification of error, and a significant reduction in the amount of transaction paperwork generated.

- Retaining audit trails to help trace errors when detected.
- Physically checking the on-hand balance both as a matter of routine (cycle counting) and on suspicion of error.

INVENTORY ACCOUNTING is presented in several sections:

Role of the Inventory Administrator

Inventory Transactions

Auditing and Error Control

Transaction Processing from Remote Locations

Transaction History and Audit Trail

Time-Stamping of Transactions

Physical Inventory Counts

Advantages of Terminal-Oriented Inventory Accounting

Role of the Inventory Administrator

Inventories are managed by people, not by computer systems. The latter are merely tools being used to gather, process, store, and output inventory-related information on which inventory management action is based.

This does not mean that inventory policies, procedures, and decision rules cannot be extensively structured and well defined so as to permit automatic execution. The objective of INVENTORY MANAGEMENT is, in fact, to automate most of the procedures and routine decisions in a computer-based system. These procedures and rules, however, probably cannot be structured to handle all conceivable developments and problems.

People must intervene to investigate, evaluate system-generated information, and make or approve decisions. This chapter mentions a number of areas where human intervention is required. The individual in question is referred to as an "inventory administrator". This generic title covers the position that in the manufacturing industry is variously called "inventory analyst", "parts controller", "inventory planner", etc.

The inventory administrator is responsible for controlling a segment of inventory and is usually assigned item coverage in one of two ways:

By product. Responsibility is assigned for an individual product or group of products. Common items are the responsibility of either a separate administrator or the administrator whose products have greatest use of the item. This is common in industries making highly customized products. It has the advantage that knowledge and control of all items for a contract or finished product is in one place.

By item type. Inventory is split by commodity or type of item – ferrous or nonferrous materials, motors, electrical components, gears, castings, etc. In this way the administrator has the advantage of experience with a complete range of similar items. For example, he knows alternative materials or components, or can group orders together for joint replenishment or common setup.

The following are some of the functions of an inventory administrator, and some of the types of intervention and decisions he makes:

- Authorizing the release of shop orders
- Authorizing the release of purchase requisitions
- Requesting cancellation of previously released orders
- Altering the quantity of a previously released order
- Revising due dates (rescheduling) of previously released orders
- Initiating a change in the master production schedule, indicated by an event such as excessive scrap of a critical part in process
- Initiating a request for expediting an order
- Coordinating the determination of effectivity of an engineering change
- Resolving contentions for items in short supply when the system does not have a clear-cut choice
- Approving an unusually large request for a withdrawal of production parts for Product Test and Engineering
- Recommending disposition of inactive or obsolete inventory items
- Asking for a physical inventory recount
- Determining whether safety stock set aside for independent customer demand can be used for production
- Changing the basis for establishing safety stock

Some of the above functions of the inventory administrator are further discussed under "Using the System" at the end of this chapter.

Inventory Transactions

The major discussion of how a particular transaction is entered is contained in the chapter that describes the system originating that transaction. The following is a summary of the major transaction sources and their basic mode of entry into the system (Figure 4):

- MASTER PRODUCTION SCHEDULE PLANNING generates changes to the requirements for end items.
- CUSTOMER ORDER SERVICING. When customer orders are entered at a terminal, *allocations* are automatically made against the product on-hand balance or the master production schedule. An allocation can be thought of as a reservation against available inventory.

  Order entry also creates requisitions for finished product shipments. These requisitions are transmitted automatically via an Action File to the shipping department or warehouse. When the warehouse is ready to pick the order, a picking list is prepared in location sequence.
- STORES CONTROL . When requisitions for products, components, or raw materials are filled, the stores employee confirms by indicating any exceptions on a terminal display of the picking list. This automatically creates stock issue transactions that reduce the "on-hand", "requirements", and "allocated" balances.

  Receipts into the stores are recorded by entering into a terminal a purchase order identification card that has been attached to the order by Receiving. Similar procedures are followed for manufactured items.

  Inventory adjustments usually result from taking a physical inventory count. They are entered via a terminal.

  Unscheduled stock issues originate from such areas as Product Test and Development. The return of unused parts is also reported via terminal entry.
- INVENTORY MANAGEMENT. Requirements are originated for items other than finished products or end items – that is, subassemblies, components, raw materials, etc. These requirements are automatically generated at the time assembly requirements are "exploded".

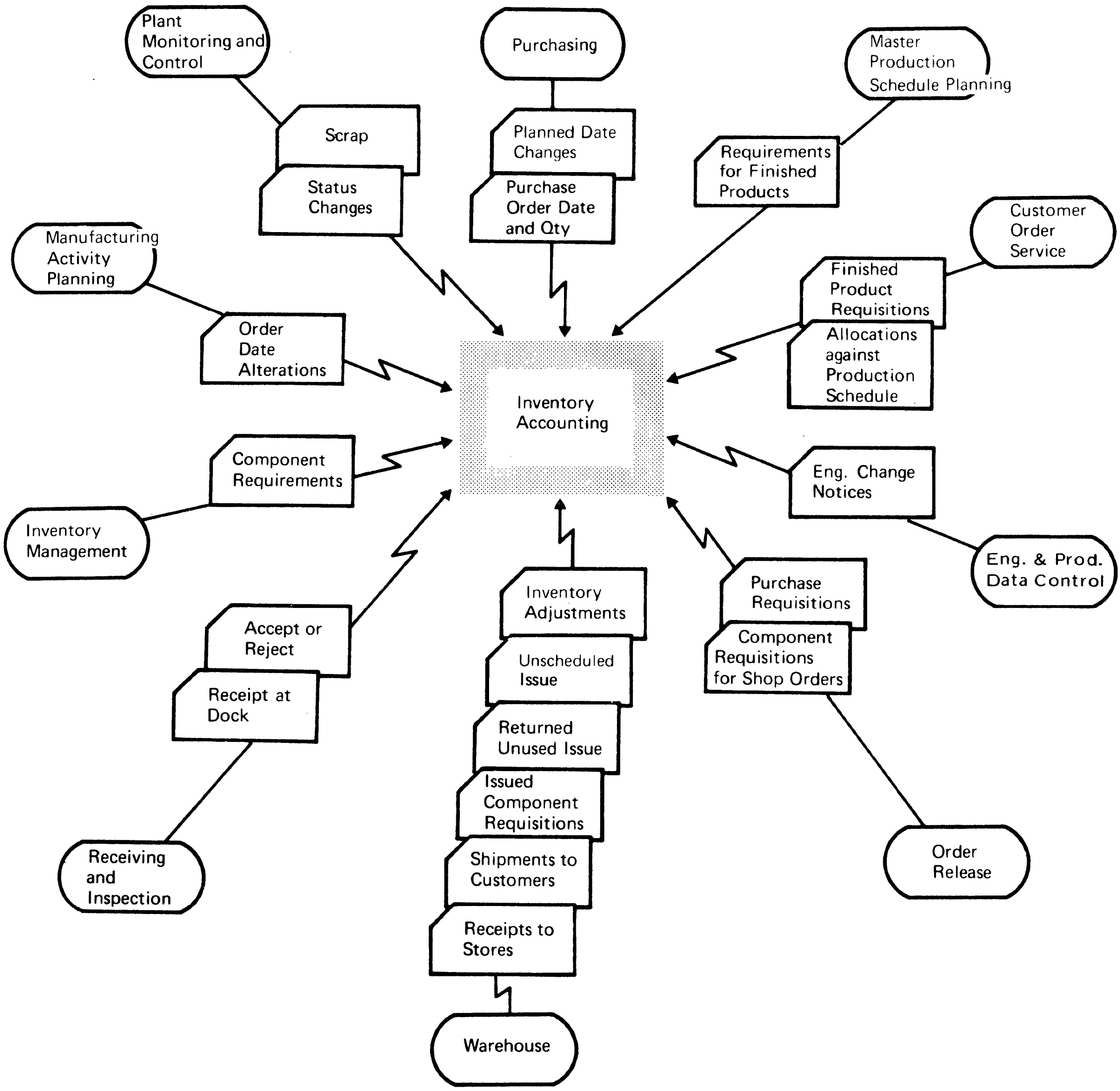


Figure 4. A summary of the major transaction types and sources

- ENGINEERING AND PRODUCTION DATA CONTROL. Engineering changes specify when requirements for the old item end, and when requirements for the new item, start. This information is entered via terminal as part of determining the most economical date to implement the change.
- MANUFACTURING ACTIVITY PLANNING analyzes the load imposed on the plant by both released and planned orders. Order release and sometimes order due dates are altered automatically by the system in light of capacity restrictions. They may also be changed by the inventory administrator through a change in order priorities.
- ORDER RELEASE. On the date scheduled for order release, the "planned" order status is changed to "released". The quantity indicated on the planned order is now recognized by the system as *on order.*

  For purchased items, a *purchase requisition* is created via Purchasing's Action File. For manufactured items, *requisitions for component parts* and raw materials are set up in a Stores Action File.
- PLANT MONITORING AND CONTROL. As a shop order progresses through the shop, scrap can be reported as a by-product of terminal-oriented labor reporting, or separately by inspectors. The shop order quantity is reduced by the amount reported scrapped. Status changes reflecting reasons for delay, location changes, in-transit status, etc., are a by-product of other terminal entries.
- PURCHASING. The placing of the purchase order is confirmed by entering the vendor number selected and any *date and quantity changes* on a terminal display of the purchase requisition. The status of the released order is updated to indicate that it has been released to a supplier.
- RECEIVING and Purchase Quality Control. Receiving identifies the physical receipt by making terminal inquiries against the open purchase order records. Upon identification, they use the terminal to enter the quantity received. Quality Control uses the identification card attached by Receiving to report via a terminal either order acceptance or quantity rejected.

Figure 5 summarizes the effect of these transactions on certain portions of the inventory records. It is not intended to be all-inclusive.

Transaction Description	On Hand	On Order	Allocated	Require-ments
Increase Master Production Schedule				+
Enter Finished Product Order			+	
Ship Finished Product	–		–	–
Explode Component Requirements				+
Create Planned Order				
Release Assembly Shop Order		+		
Create Component Requisition			+	–
Issue Component to Plant Floor	–		–	
Return Unused Components	+			
Scrap During Fabrication		–		
Receipt - Final	+	o		
Physical Inventory Adjustment	±			
Unscheduled Issue	–			
Receive Consigned Inventory	+			

Figure 5. Some common transactions and their effect on certain inventory record fields

Auditing and Error Control

Inventory records are often inaccurate because of the delay between the occurrence of an event and the recording of a transaction. The greater the delay, the greater the potential discrepancy between the recorded and the actual inventory position, and the less trust placed in the records.

In addition, errors often occur in recording the transaction. For example, recording the wrong part number on a receipt results in errors in two records. Other errors are difficult to check, such as pilferage or sending parts direct from the fabrication department to an assembly department without notifying the stores. The eventual consequence of excessive errors is usually higher safety stocks and a high incidence of shortages.

Not knowing the actual stock position also has an effect on other stores activities; for instance, assembly components are requisitioned in advance to ensure that they are physically present, thus requiring space for staging areas.

Inaccurate records also result in more queries to check actual stock and delays in orders because of not knowing when critical parts are received.

The system's auditing capabilities prevent the entry of many errors. Auditing takes two basic forms:

Checking against previous authorization

Checking for reasonableness and completeness

Checking against previous authorization

Many of the transactions entered in the system must conform to authorizations previously made as a result of other systems activities – for example:

- Requisitions for component parts should not exceed those authorized by ORDER RELEASE.
- Receipts against purchase orders should not exceed those authorized during purchase order entry.
- Finished product shipments not previously allocated to the master production schedule, or to stock, cannot be processed.
- An order that is already complete cannot have its due date altered.

The system rejects any attempts to enter unauthorized transactions, with certain exceptions. Depending on the type of terminal, the reason for the rejection can usually be visually displayed.

Checking for reasonableness and completeness

The second type of auditing primarily concerns transactions not previously planned, although it may also apply to authorized transactions. Transactions not previously planned include:

Quantity scrapped

Unscheduled stock issue

Inventory adjustments

Auditing transactions of these types can be accomplished in many different ways. Some of the common methods include:

- Checking that all data is present – for example, transaction code, order number, quantity

- Checking for reasonableness – for example, that one issue from inventory doesn't equal an entire year's supply, or that the quantity reported doesn't cause an unrealistic balance, such as a negative "on-hand" balance

Error control

Although many batch-oriented systems use the same kind of checks, there is one essential difference – namely, the interval between the time the erroneous transaction is originated and the time the originator of the transaction is asked to make a correction. If too much time elapses, the circumstances at the time of the erroneous entry cannot be recalled. This results in the inaccurate entry of corrections and, as a consequence, the need to repeat the correction cycle.

Errors detected during batch processing have to be corrected on the next batch computer run. Figure 6 illustrates that even with a daily batch cycle, the record could be inaccurate for two days, which would be considered exceptionally good in most batch processing operations. Online terminals allow transaction auditing at the source, with immediate notification and correction of errors.

Real-time auditing means that the error is detected while the reporting employee has the source document, or parts, in front of him. He is notified of the error immediately via the terminal and can check and reenter the correct transaction there and then.

Transaction control

In most cases the system uses Action Files and terminals to communicate transaction activity. Since few pieces of paper need to be generated, the transaction cannot be lost or temporarily mislaid as it can during the many steps of batch transaction processing.

Some paper is generated by the system, but only as a reminder to the employee. The system still maintains a record of the printed transaction. For example, a picking list is prepared for the stores employee who will be picking the order. However, the system maintains the list in its memory until the employee has acknowledged that he has finished the order.

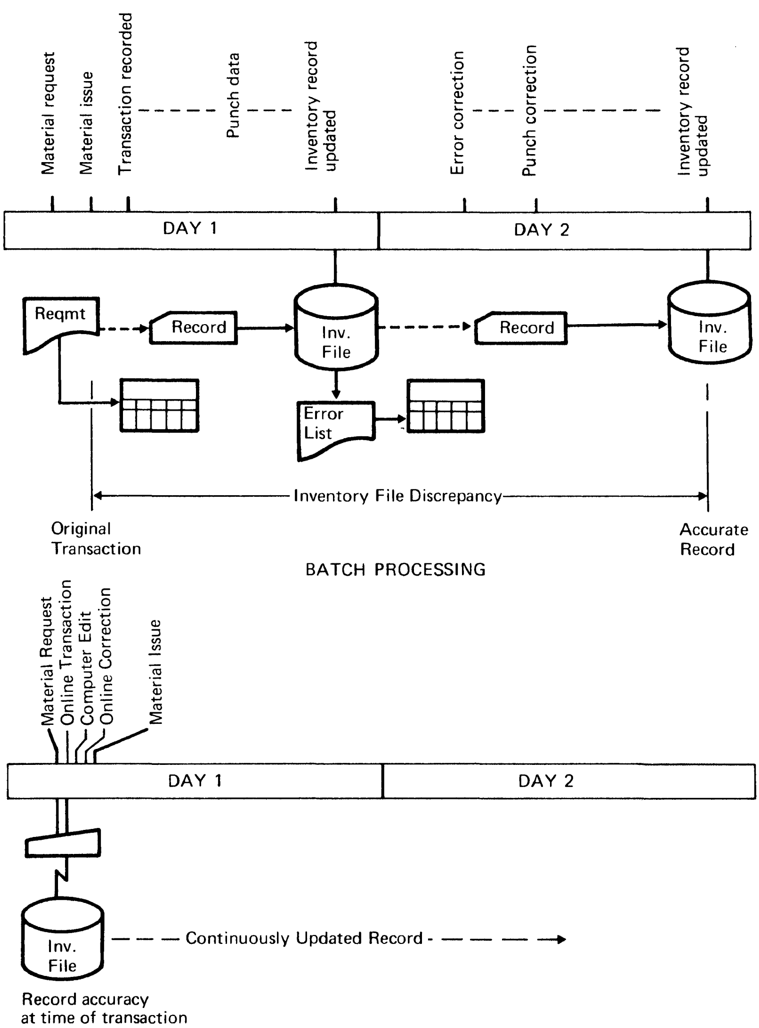


Figure 6. Online terminal entry of transactions allows immediate correction of errors. This significantly increases record accuracy

Transaction Processing from Remote Locations

Interrelated plants or field warehouses may have their own computer system or may be tied in to a centralized processing system. In either case, transactions from one location may affect the inventory records of other locations. If transmission costs are not excessive, remote online terminals can function in the same way as in-plant terminals. This extends the advantages of terminal-oriented inventory accounting to remote locations.

If distances (and therefore costs) preclude real-time processing, the transactions can be accumulated for periodic batch transmission. Detected errors can be transmitted back after batch processing.

Transaction History and Audit Trail

The ability to check back through historical transactions maintained by the system allows the source of inventory discrepancies to be traced. For example:

- What were the date and quantity for each of the last three receipts?
- What was the source of recent unscheduled issues?
- When was the last physical inventory count taken?
- Who picked the requisitions for the last stock issues?

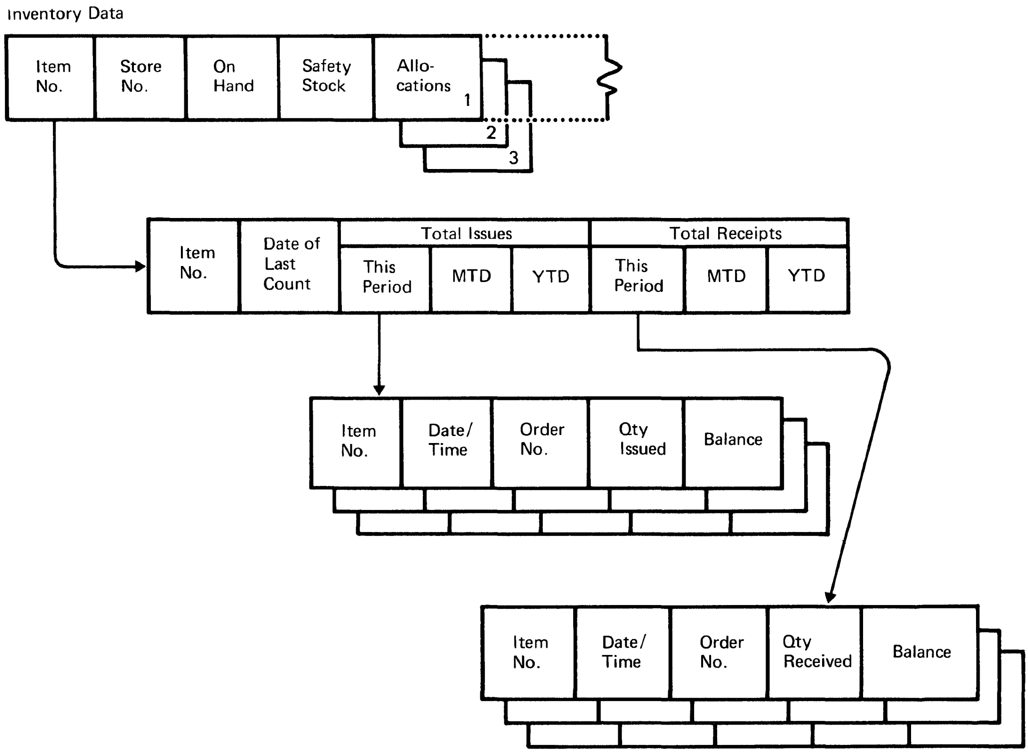
A record of transaction history may be required to enable public accountants to audit the records. In computer processing, an *audit trail* of previous transactions is usually maintained on low-cost magnetic storage. For specific reference, a high-speed printout can be obtained, with each transaction listed referring back to the previous entry for an item by means of a run number.

The more recent transactions can be stored in an historical section of the inventory file for retrieval via terminal (Figure 7). The system can be directed to keep a variable number of historical transactions for each item, say the last five receipts and the last 20 issues. The number of past transactions kept on record can be different for each individual item or group of items, depending on the amount of activity and/or the importance of the item.

Time-stamping of transactions

The system can automatically record the date and, if desired, the time of day of each transaction entry. "Time-stamping" of transactions results in a more detailed transaction history. It increases the usefulness of the audit trail and can also be utilized for certain specialized inventory management functions, such as purging obsolete parts and monitoring shelf life.

Every time a requisition is filled, the inventory record is updated to reflect the latest date of the issue. This can be periodically reviewed by the system and a report indicating slow-moving parts can be prepared (Figure 8). The index of relative movement can also be based on the percentage of total inventory moving within a time period (usually a year). Such automatically generated reports form the basis for write-off and scrapping of obsolete parts.



INVENTORY TRANSACTIONS   ITEM NO. 011850   PUMP UNIT

DATE/ TIME	BIN LOCATION	UNIT COST	RECEIPT VALUE	TRANS TYPE	REF. NO.	OLD BALANCE	QTY.	NEW BALANCE	SHORT QTY.	MAN NO.
311.1004	B107 41			ISSUE	07924	56	50	6		4021
312.1207	B107 41	1.50	9.00	RECPT	48661	6	196	202		4021
312.1410	B107 41			ISSUE	07832	202	100	102		4137
317.1300	B107 41			ISSUE	08597	102	75	27		4021
319.0809	B107 41			CHECK		27	24	24	- 3	2462
320.1604	B107 41			RECPT	52751	24	199	223		4193
325.1002	B107 41			ISSUE	09112	223	120	103		4021
325.1405	B107 41			ISSUE	09175	103	10	93		4617

Figure 7. Historical data can be retrieved to reconstruct an audit trail

SLOW MOVEMENT REPORT

ITEM NO.	DESCRIPTION	DATE OF LAST ISSUE	- - -ISSUED- - - THIS YR	LAST YR	ON HAND QTY	VALUE
446021	GEAR	5/6/-	0	200	1000	950
447093	GEAR	4/3/-	0	300	500	760
711990	SHAFT ASSEM	6/6/-	10	600	760	740
911870	BASE PLATES	1/6/-	20	500	1100	710

Figure 8. Inventory movement can be monitored to highlight candidates for obsolescence

Time-stamping of stock receipts facilitates the monitoring of shelf life for inventory items that require it. When a receipt is processed, the date of receipt is stored. If the lot of parts is separately identified by STORES CONTROL, the system can monitor parts whose shelf life is limited. The system automatically notifies the inventory administrator of those parts about to exceed their normal shelf life.

Physical Inventory Counts

Physical control over inventories is an important aspect of INVENTORY MANAGEMENT, and prerequisite to its success. It includes control over stores operations, and physical inventory counts. Stores operations are discussed in *Chapter 11, Stores Control.* Physical counts are a function of INVENTORY ACCOUNTING.

Although the incidence of transaction errors is minimized through the use of computer terminals for control over transaction reporting, inventory discrepancies still occur. Some of the reasons are:

- Errors in transaction recording. These can occur especially in those types of transactions that have not been previously planned – for example, scrap or unscheduled stock issues. Common types of error include entering the wrong quantity, entering a transaction twice, and not entering it at all.
- Errors in counts made in Receiving (or failure to count).
- Placing of parts in other than the designated storage location and not recording this.
- Reporting of an erroneous storage location.
- Pilferage or unauthorized withdrawal for miscellaneous use.

To establish confidence in the system, these errors must be corrected. More important, MATERIAL REQUIREMENTS PLANNING cannot work effectively with erroneous data. Physical inventory counting monitors INVENTORY ACCOUNTING and indicates where additional control is needed.

Inventory counts are also a legal requirement in some places for purposes of tax assessment.

Periodic physical counts

Traditionally, many companies have shut down manufacturing facilities in order to "freeze" all stock movements and take a count. Everything counted is tagged and usually double-checked. Despite this control, counting errors still occur frequently. This stems from two major reasons:

- Counting done by personnel not familiar with inventory checking procedures, such as expediters and direct production workers
- Incorrect item identification

Because of the inaccuracy, and the cost of shutting down production activity, many companies have switched to "cycle counting"

Cycle counting

Cycle counting is a rotating physical count at or near fixed intervals of time. The interval differs for each item or item class. It is normally performed by a regular team of inventory checkers. The advantages of cycle counting are:

- Critical and/or higher-value items can be checked more frequently and thus accuracy is improved where it counts the most.
- Better performance is obtained from a counting team responsible only for checking. Again, accuracy is improved.
- On suspicion of error, any item can be counted at any time, and the record verified or corrected – as a matter of routine.
- Counting is not performed under the pressure of a short shutdown.

Determining when to count inventory

The following are some of the factors the system can consider in determining when to perform an inventory check on a particular item:

- An ABC-type classification (see "Inventory Classification") – for example:

    A items monthly (high value)

    B items every four months

    C items once per year (low value)

- The point in time when stock is low. With fewer pieces to count, the job is easier, faster, and more accurate.
- History of discrepancies. The higher the possibility of error, the more frequent the count.

The system can "look ahead" and decide when it is reasonable to physically count each item. The system can then be used to prepare a priority list for counting based on all or some of the above considerations.

The checking team can be treated as a work center (as in MANUFACTURING ACTIVITY PLANNING) with a capacity limit based on the number and type of counts achievable in a day.

Reporting physical counts

Use of online terminals has the advantage that the inventory checkers can be immediately notified of discrepancies between the count they report and the system's inventory record (Figure 9). If the discrepancy is outside a predetermined percentage or value limit, the system can immediately request a recount. The immediate posting of the count to a completely up-to-date record also eliminates the usual problems of timing reconciliation.

The counting list is held in an Action File and is dispatched to the checker on a terminal located in the stores. Requests for urgent stock checks can be routed immediately. The report is made by simply entering the quantity counted on the terminal.

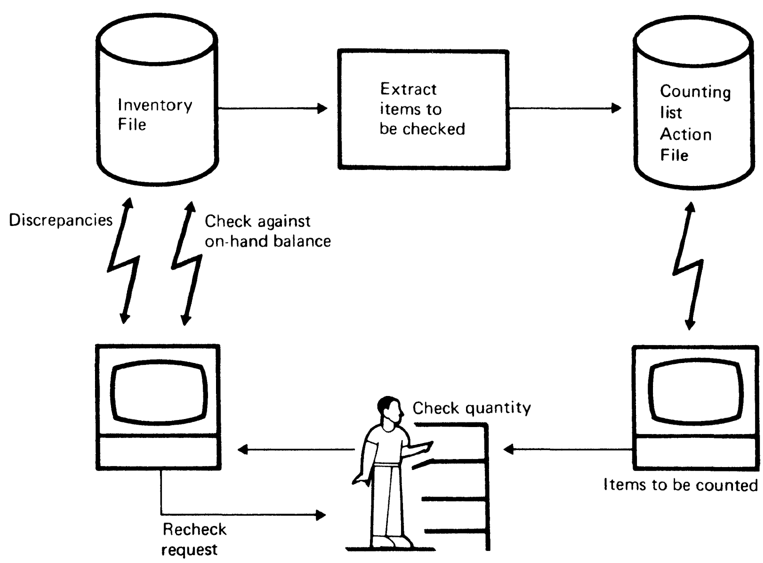


Figure 9. In cycle counting, the system generates requests for counting via a terminal that is also used to report the count

Advantages of Terminal-Oriented Inventory Accounting

With real-time auditing and correction of transactions at the source, the inventory records are as continuously in line with the actual physical position as possible. This up-to-date information permits:

- Extensive inquiry capability. A terminal inquiry into any portion of the inventory record can be made. Figure 10 shows the result of one such inquiry. Answers can be obtained to such inquiries as:

  Can an unscheduled demand be met from stock without jeopardizing the delivery of other orders?

  How has stock on hand been allocated?

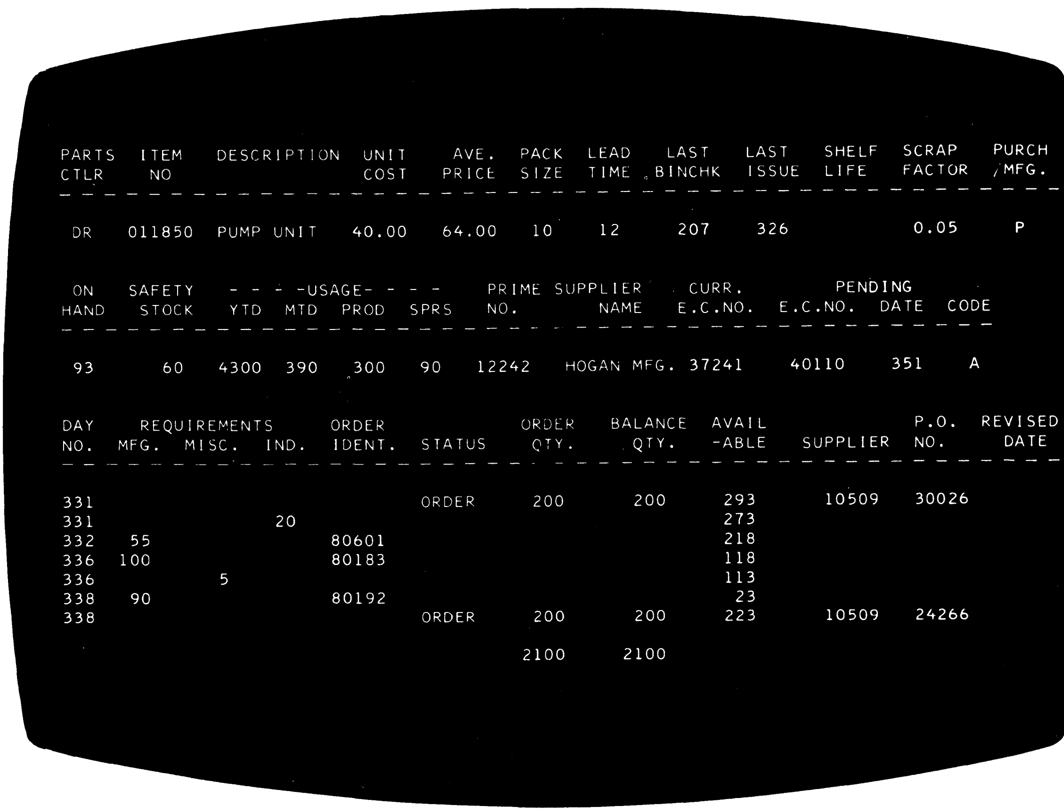
  What are the outstanding orders and what are their due dates?

- Immediate notification of out-of-line situations such as:

  Component shortages

  Excessive physical stock discrepancies

  Excessive scrap



PARTS CTLR	ITEM NO	DESCRIPTION	UNIT COST	AVE. PRICE	PACK SIZE	LEAD TIME	LAST BINCHK	LAST ISSUE	SHELF LIFE	SCRAP FACTOR	PURCH /MFG.
DR	011850	PUMP UNIT	40.00	64.00	10	12	207	326		0.05	P

ON HAND	SAFETY STOCK	- - - -USAGE- - - - YTD	MTD	PROD	SPRS	PRIME SUPPLIER NO.	NAME	CURR. E.C.NO.	PENDING E.C.NO.	DATE	CODE
93	60	4300	390	300	90	12242	HOGAN MFG.	37241	40110	351	A

DAY NO.	REQUIREMENTS MFG.	MISC.	IND.	ORDER IDENT.	STATUS	ORDER QTY.	BALANCE QTY.	AVAIL -ABLE	SUPPLIER	P.O. NO.	REVISED DATE
331					ORDER	200	200	293	10509	30026	
331			20					273			
332	55			80601				218			
336	100			80183				118			
336		5						113			
338	90			80192				23			
338					ORDER	200	200	223	10509	24266	
						2100	2100				

Figure 10. Information stored in the item record can be displayed

Terminal-oriented inventory accounting also provides advantages in:

- The use of terminals help to make on-the-spot decisions – for example:

  Reallocating parts to cover critical shortages

  Determining the effect on end product orders if off-quality items are not reworked

- Improved planning. The effect of transactions on the master production schedule can be quickly determined. The system's net change planning capability means that it is not necessary to wait until the next batch processing run before the impact of transactions is known.
- Improved inventory counts. Physical inventory counting can proceed without the need for the "freezing" of inventory movement, or for later reconciliation with unprocessed transactions still in the system at the time of counting.
- Significant improvements in accuracy. Immediate feedback of entry errors detected by authorization and reasonableness checks allows correction while the event is still fresh in the mind of the originator.
- Fewer lost transactions. The use of Action Files and the almost total lack of paperwork help ensure that transactions are not lost.
- Reduction in manual effort required to enter and confirm inventory transactions.

The subject of *component allocation* must also be mentioned in connection with INVENTORY ACCOUNTING, because this function is related to the release of assembly orders, and sometimes to the release of shipping orders.

Terminal-oriented inventory accounting provides the ideal environment for allocating components prior to the release of orders. Computer-based techniques of component allocation make physical staging (marshaling) of components completely unnecessary, especially when inventory records are continuously maintained in a valid and up-to-date position.

Components are, in effect, "staged" in computer storage instead of physically on the factory floor. The functions of allocating and de-allocating, as well as the flagging of "short" item records, notification of short components' subsequent arrival, and reallocation to held-up orders, can be performed more quickly, efficiently, and reliably than by any other method.

INVENTORY ACCOUNTING's online terminals not only permit immediate and extensive inquiries into the allocation status of orders and components, but they also, because of the system's feature of direct *data entry* via terminals, enable production control personnel and management to intervene and override the regular component allocation procedures, if required.

Doing away with physical staging of components has the following principal advantages:

- Reduced materials handling costs.
- Staging area floor space not needed.
- Elimination of "false shortages" caused by the physical allocation of a part to a held-up order when the same part is needed for the release of another order.
- Inventory accounting discipline, as expediters can no longer borrow parts from orders held up in staging.

Under the structure of COPICS, the function of component allocation is performed by ORDER RELEASE. For a fuller discussion of the subject, see *Chapter 7, Order Release.*

Inventory Planning and Control

INVENTORY MANAGEMENT, as was mentioned in the introduction, encompasses the two broad functions of INVENTORY ACCOUNTING and INVENTORY PLANNING AND CONTROL. The latter has as its primary purpose the planning of inventories and inventory order actions, but it is more than just an inventory system. It is a virtual gateway to other applications, as its outputs represent a plan that must be executed by several other systems.

Within COPICS, the following systems directly depend on, and are "driven" by, the main output of INVENTORY PLANNING AND CONTROL:

MANUFACTURING ACTIVITY PLANNING

ORDER RELEASE

PLANT MONITORING AND CONTROL

PURCHASING AND RECEIVING

STORES CONTROL

These systems, in themselves, cannot compensate for any deficiencies of the materials plan generated by INVENTORY PLANNING AND CONTROL, even though they might execute it in a superb fashion. It is extremely important, therefore, to implement and operate INVENTORY PLANNING AND CONTROL in such a way as to ensure that its outputs are valid, accurate, complete, and up to date at all times.

INVENTORY PLANNING AND CONTROL, through its function of MATERIAL REQUIREMENTS PLANNING, actually performs three major tasks:

- It plans material requirements and inventory order actions.
- It determines production capacity requirements, through the "planned orders" that it projects over the materials planning horizon.
- It helps set and regulate shop priorities, through the order due dates that it establishes and keeps valid following order release.

In addition to *planning* materials and priorities, INVENTORY PLANNING AND CONTROL generates information (used directly, or after processing by other systems) on which *control* over these materials and priorities is based.

The Nature of Demand

The selection of techniques used to plan and control inventories in a manufacturing company depends on the nature of demand for the respective inventory items. There are two alternate basic approaches, or two sets of techniques, that have been employed:

- Order point techniques (statistical inventory control)
- Material requirements planning

"Order point" utilizes data on the historical behavior of an inventory item, whereas "material requirements planning" works with data defining the relationship of components of an assembled product (bill of material), and with the requirements stated by the master production schedule.

When analyzing and classifying inventory, it is not enough to examine only the quantitative attributes of the individual parts, such as cost, lead time, past usage, etc. An all-important attribute, the *nature* of demand, must not be overlooked.

The nature of demand is the real key to inventory management technique selection, and applicability. The fundamental principle that has served as a guideline to the applicability of either statistical inventory control or "material requirements planning" is the concept of *dependent* vs *independent demand.*

Demand for a given inventory item is considered *independent* when it is unrelated to the demand for other items, particularly higher-level assemblies or products. Demand is independent when it is not a *function* of demand for other inventory items. Independent demand must be forecast.

Conversely, demand is considered *dependent* when it is directly related to, or derives from, the demand for other items or end products. Such demand can, of course, be calculated. Dependent demand need not, and *should not*, be forecast. It can be determined from the demand for those items to which it is a component (as raw material, or a component part, or a subassembly).

Forecasting attempts to use past experience to determine the shape of the future. Forecasting succeeds only to the extent that past performance is repeatable. But in a manufacturing environment, future demand for a given part may be quite unrelated to its past demand.

It is possible, of course, to forecast demand for dependent components and subassemblies. However, this is not desirable because requirements for components can be determined better by exploding the bill of material for the assemblies and products comprising the master production schedule. Demand for these components can be *calculated* much more accurately than it can be forecast, by whatever forecasting method. Forecasting, therefore, should be applied only at the end item or finished product level.

Figure 11 indicates the characteristics of demand for common classes of inventory.

Inventory Type	Demand Type	Note
Finished Products	Independent	
Service Parts	Independent	
Options and features on finished Products	Independent	Considered independent when ordered by customer
Subassemblies	Dependent	As will be indicated later, some of these may be treated as independent.
Component Parts	Dependent	
Raw Material	Dependent	
Semifinished	Dependent	
Tools	Dependent	This assumes data exists on the bill of material or routing from which to derive demand.
Office supplies	Independent	Small Tools, disposable Tools
Production supplies	Independent	If data exists in the routing from which to derive demand, it should be treated as dependent.
Maintenance Parts 1. Use on PM and planned repair	Dependent	See Chapter 9 for more detail.
2. Use on breakdown	Independent	

Figure 11. The characteristics of demand for common classes of inventory

The demand for a product or end item (including service parts) may have to be forecast, but none of its component items need be forecast. When components are forecast independently, their inventories will not usually match assembly requirements well, and the cumulative service level will be significantly lower than the service levels of the parts taken individually.

This is caused by combining the individual forecast errors of a group of components needed for a given assembly. If there is a 90% chance of having one item in stock when it is needed, two related items needed *simultaneously* will have a combined chance of 81% of being in stock. With ten items, the odds of all of them being available are only 35%. Even with the service level set at 95%, the odds on ten items would be no better than 60% (see Figure 12).

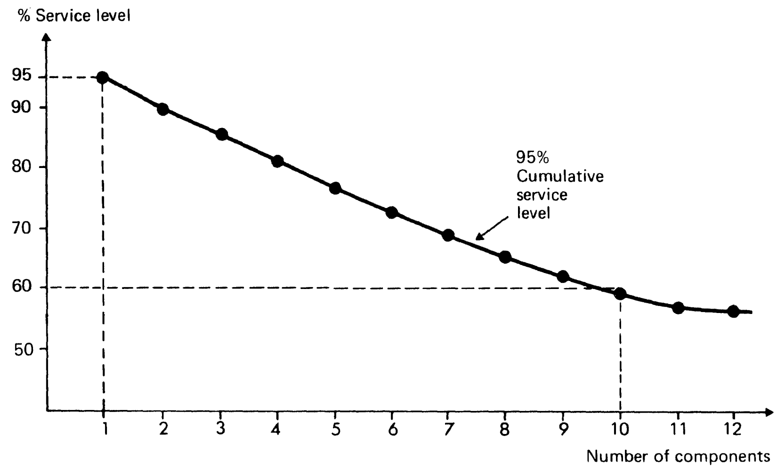


Figure 12. The chances of all components being available at time of assembly diminish very rapidly as the number of components increases

This kind of service would be unacceptable at the finished product level, but in many companies there is such a low service level between component and assembly. Expediting, rush work, and an increase in manufacturing costs compensate for this.

Another way of visualizing the timing problem is shown in Figure 13. Each time requisitions for components of assembly A are issued, a different component is out of stock. MATERIAL REQUIREMENTS PLANNING helps avoid this by using planning techniques to coordinate component delivery on all required parts and plans to achieve a 100% availability of components.

Order Point vs Material Requirements Planning

Order point (statistical inventory control) techniques assume relatively uniform usage, in *small increments* of the replenishment lot size. When this basic assumption of *gradual inventory depletion* is grossly unrealistic, the techniques of "order point", "safety stock", and "economical order quantity" will be invalid.

For components of assembled products, requirements typically are anything but uniform, and depletion anything but gradual. Inventory depletion tends to occur in discrete "lumps" because of lot sizing at higher levels.

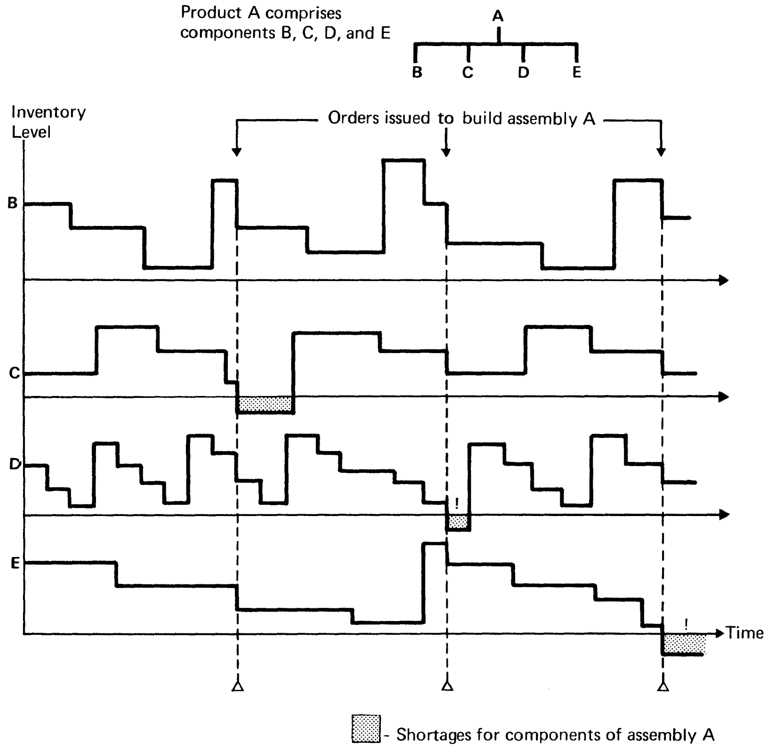


Figure 13. The coordination of all components used in an assembly is the job of MATERIAL REQUIREMENTS PLANNING. When planning for dependent demand parts, timing is more important than safety stock

In most cases, the demand for dependent demand items is discontinuous or "lumpy". For example, there may be several periods of little or no demand and then a sudden surge of demand. Figure 14 shows the reason for lumpy demand. Even though forecast customer demand is fairly level, the products are built in lot sizes in order to reduce setup costs. The demand for components is dependent on when the products are built. In the example there are two periods of zero demand before a demand of 30 is encountered. This demand pattern, very common for component parts, cannot be effectively handled by forecasting techniques.

Components often are not available when actually needed because they have been ordered independently of the *timing* of end item requirements. Even with high safety stock, if two or more different assemblies require an "order point" component simultaneously, it may not be available in sufficient quantity because order point techniques assume that annual demand will average out (on, typically, a weekly basis).

Period	1	2	3	4	5	6	
Customer Demand	10	12	12	14	12	12	
Build Schedule			30			30	
Component Demand		30			30		

On Hand = 35
Safety Stock = 5

Figure 14. Demand for components can be lumpy because of lot sizing at higher levels

The fact that some manufacturing companies use order point systems, maintain safety stocks on components, and still get most orders shipped on time may seem to contradict the above observations. However, such companies do so by carrying unnecessarily high inventories and doing a great deal of expediting. The expediter usually has some kind of a "hot list" of assembly shortages and, regardless of the due dates that the inventory system has put on components orders, tries to get the right items to the assembly floor.

However, he faces a dilemma with this hot list. If he expedites only those shortages that already exist on the assembly floor, it is obviously a case of too little too late. If he tries to anticipate shortages and expedite these, he has an extremely long hot list and the foreman's logical question is, "Which do you want first?" To do an effective job, he really needs a series of hot lists. He needs to break down assembly floor requirements into time periods and indicate by period what the future requirements will be. This concept, extended through enough time periods to cover the entire manufacturing lead time, is, in effect, the basis of the technique variously called "material requirements planning", "time-phased material requirements planning", or "time series requirements planning".

Material requirements planning systems represent the correct solution to the problems discussed. Such systems embody a set of techniques designed expressly for companies with assembled products whose parts and raw materials have a demand that is, by definition, dependent. This type of system is a set of procedures and decision rules designed to determine requirements of inventory items, as to both quantity and timing, on all levels below the end product, and to generate order action to meet these requirements.

Because of the high data volume that must be handled by a material requirements planning system in a company with tens and sometimes hundreds of thousands of records, as well as because of the high frequency of replanning, requirements planning represents a job that can be done only on a computer.

Integrating Alternative Techniques into One System

Within INVENTORY MANAGEMENT, techniques for the management of both dependent and independent demand items are combined and integrated in INVENTORY PLANNING AND CONTROL. The format used is that of MATERIAL REQUIREMENTS PLANNING, into which records for independent demand items are incorporated.

Historically, order point techniques have been used primarily on finished products and service parts. Material requirements planning techniques apply to *component items.* These include:

- Raw materials
- Purchased components of assemblies
- Fabricated (manufactured) components of assemblies
- Subassemblies
- Semifinished items

While end products and service parts are generally subject to external, independent demand, their component items are not. Raw materials and component parts, both purchased and fabricated, that "go into" independent demand items, have demand that is dependent, and they are therefore subject to material requirements planning techniques.

time-phased "order point"

INVENTORY PLANNING AND CONTROL utilizes time-phased material requirements planning, which means that in order to plan requirements of end product and service part component items, their "order point" records must be in *time-phased format,* with the same materials planning horizon as for other, dependent demand items.

This means that the forecast of demand for, say, a service part is extended beyond the immediately next point of replenishment. Whatever the forecasting model (see *Chapter 3, Forecasting*) used for a given "order point" item, it is applied to provide an estimate of future demand over the entire planning horizon. This permits the system to generate "planned orders", that is, the estimated number and timing of future replenishment orders. Figure 15 illustrates this concept.

ON HAND	= 750
FORECAST	= 100/PERIOD
SAFETY STOCK	= 300
ORDER QUANTITY	= 400
LEAD TIME	= 3 PERIODS

		PERIOD									
		1	2	3	4	5	6	7	8	9	10
Projected Requirements		100	100	100	100	100	100	100	100	100	100
Scheduled Receipts (on order)											
On Hand	750	650	550	450	350	250	150	50	-50	-150	-250
Planned Order Release			400 ←			┘	400 ←			┘	

Figure 15. Time-phasing an "order point" item

It should be noted that in a time-phase record format the traditional order point itself actually disappears. It is no longer necessary to calculate it. The system plans for the replenishment order to arrive when the quantity on hand has dropped down to the safety stock level, and the material requirements planning logic positions (offsets) the planned release of the future order properly on the time scale. The result is exactly the same as if order release were geared to reaching the order point.

In the example (Figure 15) the order point would be 600 (safety stock of 300 and demand during replenishment lead time of 300). The system will order in period 2, during which the quantity on hand will have reached 600, and again in period 6, when the currently projected quantity (150 on hand by the end of the period) will have been increased by the first planned order, or 400.

The quantity and timing of these planned orders, in turn, determines the requirements for component items (see "Material Requirements Planning"). It should also be noted that in the case of manufactured "order point" items, the time-phase "planned orders" provide the basis for developing production capacity requirements (see *Chapter 6, Manufacturing Activity Planning*).

An inventory item may be sold as a service part and also used as a component in a product being manufactured. Therefore, it has two sources of demand, independent and dependent. MATERIAL REQUIREMENTS PLANNING maintains separate records for each of the demand sources. The system automatically combines the requirements by summarizing the two types of demand in a time-phased format.

In the system description that follows, the individual procedures and techniques are discussed within the framework of MATERIAL REQUIREMENTS PLANNING. Dependent demand is assumed throughout the discussion. Where different treatment applies to independent demand items, it is discussed on the basis of an exception to the general rule.

Material Requirements Planning

Quantities of all raw materials and components below the end item level, and their timing required to support the master production schedule, are determined by MATERIAL REQUIREMENTS PLANNING. This system has as its prime source of input net changes to the previous master production schedule (see *Chapter 4, Master Production Schedule Planning*).

In the case of make-to-order manufacturing, or with small, standard products made to stock, these two schedules may be identical. Where the manufacturing lead time exceeds the delivery lead time, the scheduling of final assembly must typically await the receipt of actual customer orders. The master production schedule therefore does not normally equate with the final assembly schedule, but can best be thought of as a plan for component and subassembly availability, to allow certain end products to be scheduled for final assembly, in the future.

Approaches to Material Requirements Planning

There are two basic approaches to material requirements planning. The first, which is the traditional approach, is called "requirements regeneration". Under this approach, the entire master production schedule is exploded via the bill of material. Against gross requirements thus generated, the available inventory on hand and on order is, in effect, allocated in a level-by-level process.

As each new issue of the schedule is authorized, or as changes are made in the existing one, the process is repeated. Each regeneration represents a fresh start, in that all previous planning is discarded and inventories are reallocated. Because the entire schedule must be reprocessed, the amount of computer time consumed is considerable. For reasons of economy, therefore, such regeneration of requirements is performed at limited frequency – typically once a month or once a week.

Changes in the master production schedule are accumulated after each regeneration run, and total requirements are recomputed at the end of the specified period. Changes in requirements, however, normally occur continuously rather than periodically (Figure 16) and the exact effect of these changes is not known until the next regeneration run. A considerable length of time may elapse before the impact of important events affecting materials planning becomes explicitly known. Because of the periodic, batch-mode approach, this type of system is actually out of date, in some degree, at all times.

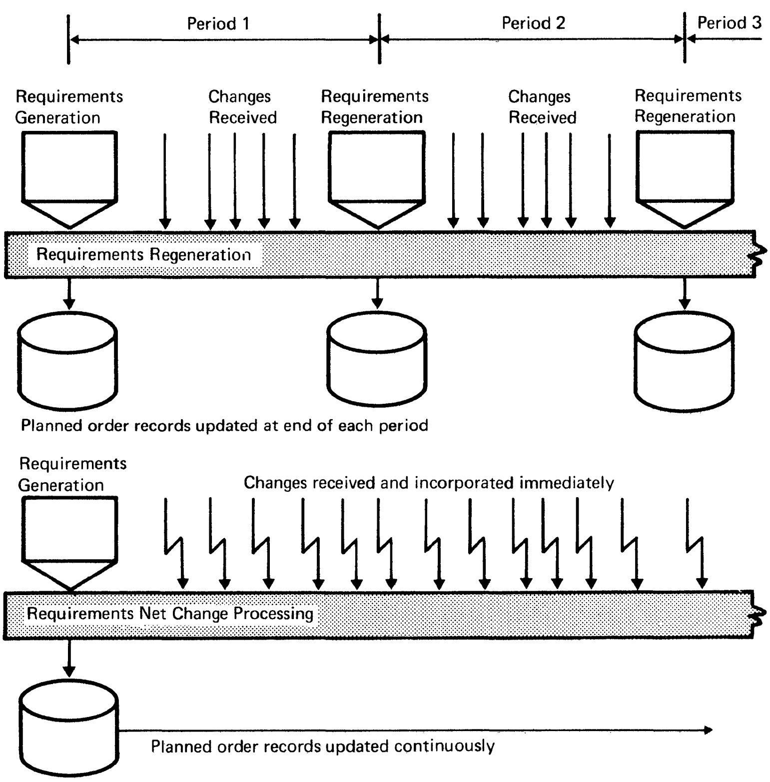


Figure 16. Net change processing provides an up-to-date picture of requirements and orders at all times

net change Material Requirements Planning

The second approach to material requirements planning, called "net change", is designed to process only incremental changes in the master production schedule, and to incorporate the results into the existing plan.

This approach is called *net change* because only the net difference between consecutive issues of the master production schedule is input to the system. The amount of processing is correspondingly reduced and, in comparison to the regeneration technique, more frequent processing runs become feasible. This, in turn, permits individual schedule changes to be processed as they arise between the periodic issues of the formal master production schedule.

Figure 17 illustrates the principle of net change processing. The difference between the old and the new schedules is a net increase of two units of product A for periods 5 to 7. This would be the only data used to start the bill of material explosion, which would correspondingly affect only a limited number of inventory items.

Net change material requirements planning may be performed in batch mode at frequent intervals, typically once a day, or as a continuous, online application. The latter represents a so-called *transaction-driven* system that accepts all transactions, including schedule changes, in a random input stream.

Only a continuous net change system has the capability of actually being completely up to date at all times. A batch-oriented net change system may be slightly out of date despite a high frequency of processing. For example, a daily batch system can be out of date by up to 24 hours.

Period		1	2	3	4	5	6	7	8	
OLD Production Schedule	Prod. A	10	12	12	14	14	12	12	10	
	Prod. B	50	50	50	50	50	50	50	50	Exploded with regeneration
NEW Production Schedule	Prod. A	10	12	12	16	16	14	14	10	Exploded with regeneration
	Prod. B	50	50	50	50	50	50	50	50	Exploded with regeneration
NET Difference	Prod. A	0	0	0	+2	+2	+2	+2	0	Exploded with net change
	Prod. B	0	0	0	0	0	0	0	0	

Figure 17. With the net change approach, only the difference between schedules is exploded

Other than changes in the master production schedule, events triggering a change in stock status include:

transactions causing a change in stock status

- Engineering changes concerning removal and additions of bill of material items, changes in the usage quantity, and the engineering change effectivity date
- Inventory transactions such as excessive scrap, inventory discrepancies detected during physical counts, large unscheduled issues, or a higher than expected rate of customer demand
- Changes in inventory policy, such as alterations in the customer service level or changes in the rules to determine the size of an order
- Alterations in the policy of suppliers, such as changes in lead time or the minimum shipping quantity

The net change approach determines the effects of these events as they are presented to the system. If inventory surpluses or safety stocks cannot absorb the change, alterations in inventory records are made through all levels until the new requirements are covered (Figure 18). If, on the basis of the information supplied, the alteration cannot satisfactorily be made, the inventory administrator (analyst) is notified.

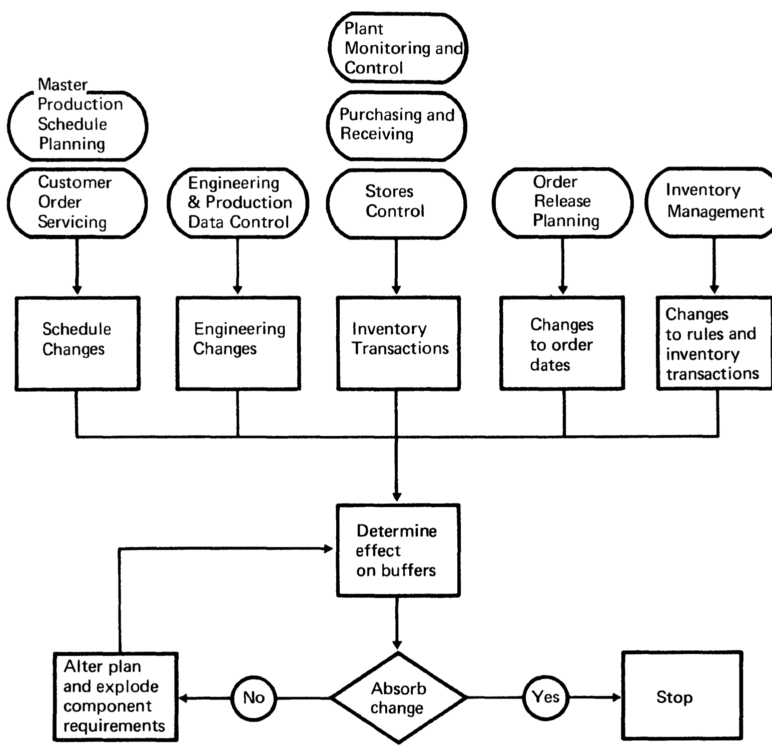


Figure 18. Changes to the materials plan come from many sources. They are processed until the changes can be absorbed, or covered by new orders.

The net change approach also allows the effect of the acceptance of an order, or a significant schedule change, to be tested in advance. If acceptance will cause material shortages that cannot be resolved, an alternate date or quantity can be entered on a trial basis, and quickly processed (see "Trial-Fitting a Proposed Schedule Change").

considerations in net change processing

Net change represents a fundamental departure from the traditional approach to material requirements planning. It offers significant advantages in terms of reaction to change, and up-to-date records at all times. It is the mode of operation to be preferred when online inquiries into the inventory data are desirable and when the ability to replan swiftly is important.

The fact that online terminals are being used in connection with the inventory management system does not, however, make it imperative that inventory transactions be processed in "real time", as would be the case with the *continuous* net change approach. Processing need not be triggered immediately upon entry of a transaction at a terminal. Transaction data can be temporarily stored in the system and processed periodically, say daily. The system will then be up to date as of the last transaction processed. Conversely, the less delay in presenting transactions to the system, the more up-to-date it will be.

How up-to-date an inventory management system should be is up to the individual company, in each specific instance. Net change material requirements planning will in any case provide more current data than would ever be feasible under the requirements regeneration approach. With continuous net change processing, the system may always be kept completely up to date.

net change vs regeneration

Net change may be less efficient in computer usage than requirements regeneration. However, in terms of the whole materials control function of the company, net change is much more effective. Like many other business applications, there is a tradeoff between data processing efficiency and business efficiency. In these cases, data processing efficiency should never be a primary objective, but should be subordinated to the larger goal of improving the effectiveness of the business.

When comparing the relative efficiency of the net change vs regeneration methods of material requirements planning, it should be understood that such efficiency is related to the *scope* of change in the master production schedule. When a really major change occurs, it can be reprocessed more efficiently using requirements regeneration techniques.

In companies that implement a net change material requirements planning system, regeneration will seldom have to be used. However, a requirements regeneration program would be substituted on certain occasions, as follows:

- When making the initial explosion (file creation)
- When many items on the master production schedule suddenly change significantly, as might be the case whenever a major change in the market takes place
- When major alterations to inventory policy have been made – for example, a complete revision of the customer service level, or a general change in lead times or in the rules determining order size
- When errors may have crept into the system and the regeneration is performed to purge it

discipline needed for Material Requirements Planning

The need for discipline in transaction reporting, and in the physical control over inventories, has previously been discussed. No material requirements planning system can succeed without management enforcing such discipline.

With requirements *regeneration,* the old plan is literally thrown away every time a new version of the master production schedule is authorized. The explosion starts again from scratch. This has the advantage of discarding old errors, plus data made invalid by change, along with the old plan. However, unless the inventory and bill of material records are accurate and up to date, the new plan will include built-in errors that will cause shortages, expediting, and the ordering of wrong parts.

Net change requirements planning is a continuous system that must be continuously maintained. The old plan is retained and modified with current changes. This system presupposes that high data integrity can be sustained in both transaction entries and record maintenance. Before installing such a system, a company must be prepared to impose and maintain the required degree of procedural discipline outlined in *Chapter 11, Stores Control* and other chapters. Unless and until management of a given company creates such a climate of discipline, that company can never attain a fully effective inventory management system.

The need for discipline pertains not only to the reporting of inventory transactions, but also to the maintenance of bill of material data and the master production schedule, as well as to the procedures governing engineering changes and product releases.

basic steps in Material Requirements Planning

The basic steps, or individual functions, of MATERIAL REQUIREMENTS PLANNING are as follows:

- Determination of gross requirements
- Calculation of net requirements
- Application of safety stock and safety lead time
- Consideration of order quantity
- Scheduling of planned order release
- "Explosion" of end item requirements throughout the product structure

A more detailed discussion of these functions follows, in the above sequence.

Gross requirements

Gross requirements for items covered by MATERIAL REQUIREMENTS PLANNING can be viewed as coming from four separate "directions":

- End item requirements (and sometimes major interplant, export, and service part requirements) are stated by the master production schedule.
- Requirements for parts other than end items can come from several sources external to the system, such as an independent service parts organization, interplant, Maintenance, Engineering, etc.
- Requirements of items with independent demand. These are generated internally by projecting the forecast over the materials planning horizon, as discussed previously.
- Dependent demand requirements, generated by the "explosion" of requirements throughout the several levels of the product structure.

The system combines these requirements, as necessary, and summarizes them into statements of gross requirements by item number.

requirements from Master Production Schedule Planning

The various steps involved in developing a master production schedule are discussed in *Chapter 4, Master Production Schedule Planning.* They are summarized, in simplified form, in Figure 19.

In most cases, the master production schedule will contain end items only. These are either end products, or the highest-level assemblies recognized by the bill of material. Where demand for certain major service or interplant items is significant, they may be included in the master production schedule even though they are not on the highest level of the product structure.

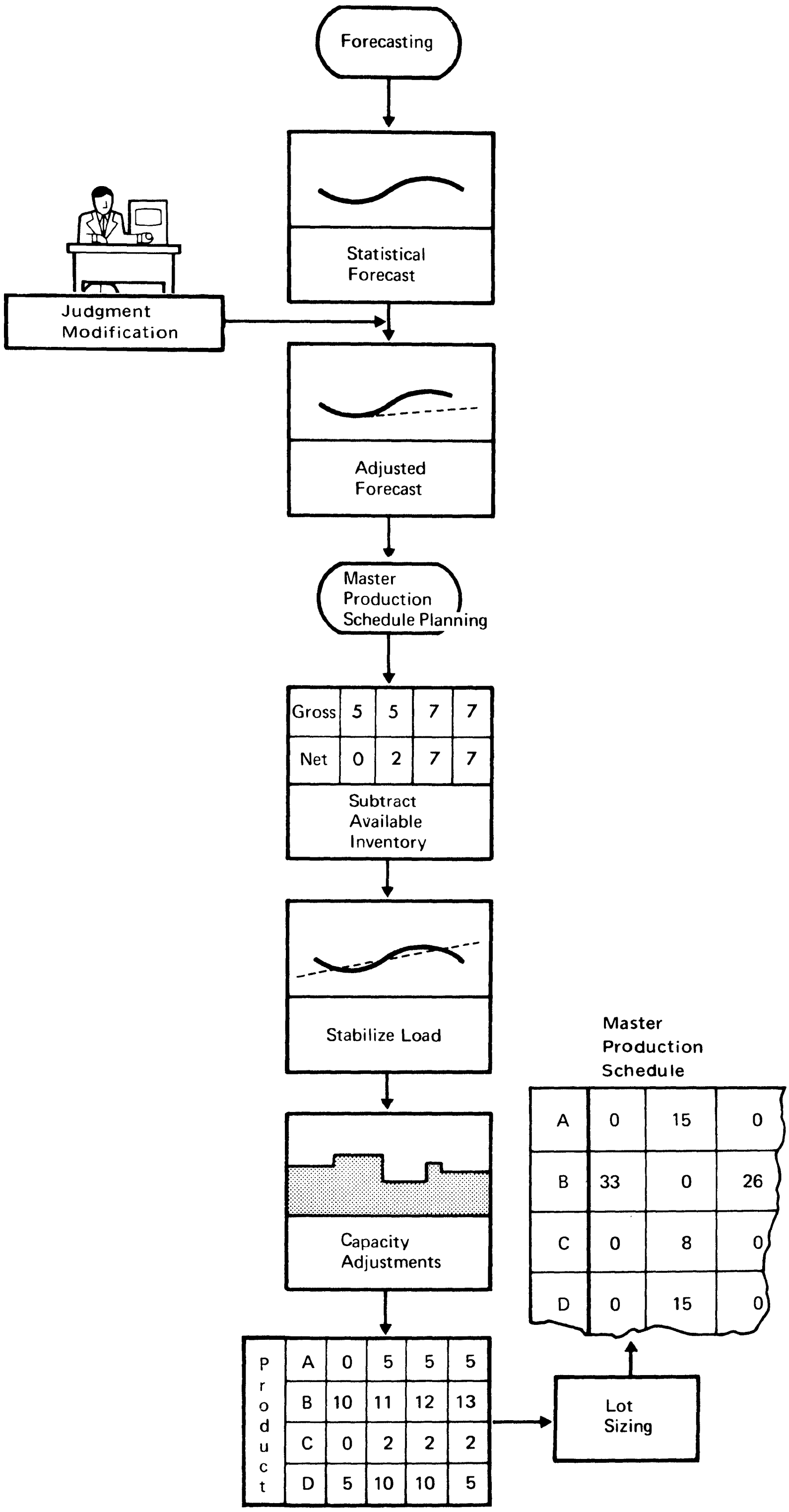


Figure 19. The master production schedule, used to explode component part requirements, is the result of several system steps

The contents of the master production schedule are entered into MATERIAL REQUIREMENTS PLANNING as gross requirements for the respective items. A net change approach, however, does not involve an explosion of the entire master production schedule. A new master production schedule is compared with the existing, or previous, schedule. The difference is calculated and passed to MATERIAL REQUIREMENTS PLANNING as a net change (Figure 20).

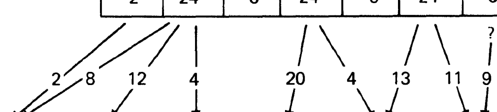
Since forecasts are usually revised weekly or monthly, these types of net change will normally occur in batches. However, modifications of forecasts based on judgment, or other changes, may occur at any time and be processed immediately.

A change may result from allocating customer orders. Allocation is the assignment of available or planned inventory to an order. In CUSTOMER ORDER SERVICING, as customer orders are entered, available inventory and planned production (Figure 21) are allocated against them.

Period	1	2	3	4	5	6
OLD Schedule	24	0	24	0	0	24
NEW Schedule	24	0	24	0	24	0
NET CHANGE					+ 24	–24

Figure 20. Only a net change to the master production schedule is actually input to MATERIAL REQUIREMENTS PLANNING

On Hand	Production Schedule					
	1	2	3	4	5	6
2	24	0	24	0	24	0



Quantity	10	12	4	20	17	20
Period Due	1	1	2	3	5	5
Customer Order Number	10561	10612	10699	10744	10884	10928

Figure 21. Excessive customer order allocations against the master production schedule result in a net change

Allocations may be considered a reservation against the master production schedule. If, using the example in Figure 21, a commitment is made to a customer to deliver 20 units in period 5, the master production schedule must be revised to reflect the additional commitment. In this case, an additional 9 units must be planned for period 5. The increase is processed as a *net change* in MATERIAL REQUIREMENTS PLANNING. If this is not practical, other action must be taken such as deferring other orders or quoting a new delivery date to the customer.

Requirements for product variations and options represent a special problem. If bills of material are structured properly, determining requirements for product variations can be approached in the same way as for finished products. Figure 22 shows that product A has four basic options: B, C, D, and E. The number of variations of the options ranges from 2 for option D to 9 for option E. If an attempt is made to maintain a bill of material for every possible combination, 648 different bills must be stored, and 648 different items must be forecast and maintained on the master production schedule. With this approach, small increases in the number of products or options would create so many different bills of material that material requirements planning would become impossible.

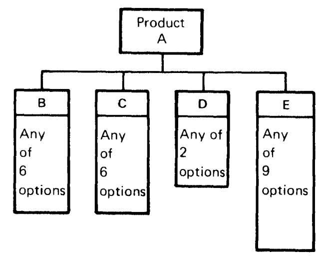


Figure 22. A basic product may have many options and variations

The solution is to treat the options and variants as end items. This can be done by setting up a separate bill of material for the parts common to all models and separate bills for the options and variations (see *Chapter 1, Engineering and Production Data Control*). The number of bills can then be reduced to 24. Techniques used to forecast product variations and optional features are discussed in *Chapter 3, Forecasting.*

requirements from external sources

Demand for items on any level of the product structure, that is, for items not appearing on the master production schedule, is entered as a gross requirement directly against the respective item.

Several sources external to MATERIAL REQUIREMENTS PLANNING can generate demand for such items – for example, interplant or export demand for miscellaneous parts. Another example is orders for quantities of service parts, placed by a field warehouse, by a service part department that maintains its own service part inventory control system and stores, or by a wholesale distributor. Such orders would call for future, not immediate, delivery as the "customer" carries his own stock and forecasts his own demand.

Requirements in this category can also come from product development and experimental departments, from Product Test, from Maintenance, etc. If their needs for inventory items are planned in advance, they can be entered as gross requirements. Immediate requirements of this type would be treated as an "unscheduled issue" inventory transaction.

requirements for independent demand items

As discussed previously under "The Nature of Demand", requirements for items that have independent demand must be forecast. Within the framework of COPICS, all forecasting techniques and procedures are embodied in FORECASTING, and are discussed in detail in *Chapter 3.*

INVENTORY PLANNING AND CONTROL establishes safety stock levels for independent demand inventory items, using the techniques of FORECASTING. Safety stock data is maintained by the system, and is considered in generating order action requests (notices) automatically.

The calculation of safety stock is performed by INVENTORY PLANNING AND CONTROL, and the results are incorporated in the product definition data record (see *Chapter 1, Engineering and Production Data Control*). Further discussion of safety stock will be found under "Safety Stock and Safety Lead Time", later in this chapter.

Gross requirements for independent demand items are generated by extending the forecast for each such item over the entire materials planning horizon, and maintaining it in time-phased format, as was previously discussed (see Figure 15).

This applies primarily to service parts, in those cases where such parts are supplied to end users from factory stock. Finished products may also be subject to the same control techniques, but the respective records are not part of MATERIAL REQUIREMENTS PLANNING. Their gross requirements are entered via the master production schedule (see *Chapter 4, Master Production Schedule Planning*).

In the context of MATERIAL REQUIREMENTS PLANNING, product gross requirements represent *production* requirements, rather than customer demand. If the forecast customer requirements are "netted" against finished goods inventory during the preparation of the master production schedule, they must not be "netted" a second time in MATERIAL REQUIREMENTS PLANNING.

Other types of independent demand items, such as consumable tools, maintenance parts, and supplies, are treated the same as service parts, except for "slow movers".

low usage items

Many independent demand items for which inventory is maintained have very low usage. Slow-moving items are generally considered to be those for which average demand in a period is in the same range as the average deviation of demand (MAD). For example, in Figure 23, the average demand is one per period; the deviation from average, however, is 1.2. This type of item is difficult to control using conventional statistical inventory control techniques.

Period	1	2	3	4	5	6	7	8	9	10
Demand	0	2	0	3	0	0	0	4	0	1

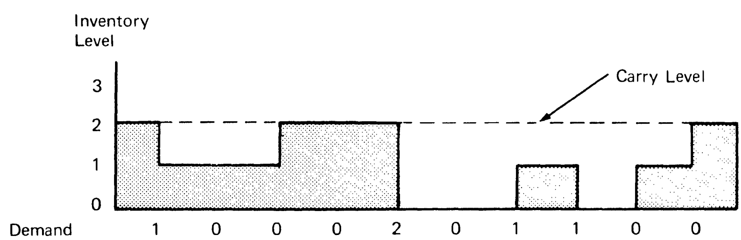
Average = 1.0
MAD = 1.2

Figure 23. An example of a demand pattern for a slow-moving item

There are several different ways to control slow-moving items. Two will be briefly discussed:

- Carry level
- Demand distribution analysis

Carry level establishes a quantity that the system constantly strives to maintain (order "up to"). For example, if a carry level of two were established, and one were issued, a replenishment order would be generated for a quantity of one (Figure 24). Economical order or handling quantities are not considered.



Replenishment Lead Time = 2 Periods

Figure 24. A carry level used for slow-moving items is the quantity the system tries to maintain at all times

For many items, especially maintenance parts, setting the level is a matter of judgment. However, the carry level can be set after a simulation of demand and replenishment cycles. Then, on the basis of annual volume and average replenishment lead time, a designated service level percentage will select a carry level value from a table.

Demand distribution analysis is based on an historical evaluation of demand during replenishment lead time. Figure 25 shows the basis of the analysis.

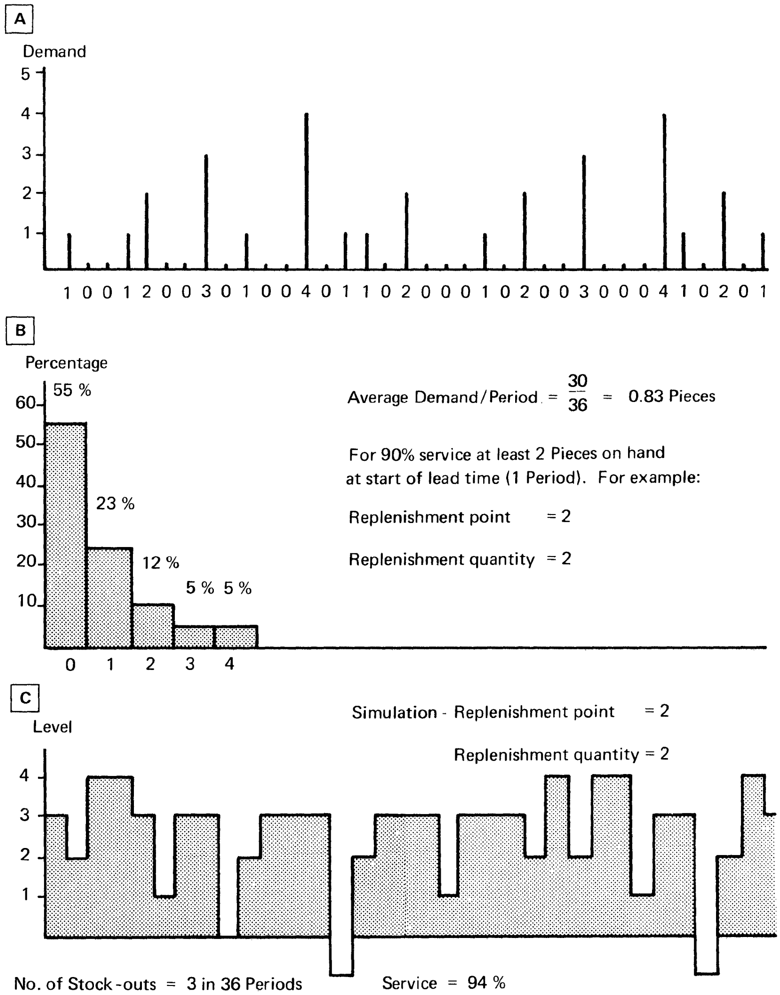


Figure 25. Analysis of past demand during a replenishment lead time can be used to select a stock level for slow-moving items

Figure 25A shows actual demand for a series of lead time periods. The system constructs a frequency distribution of demand (Figure 25B). Analysis of the distribution shows that if a quantity of 2 is on hand at the beginning of each period, a 90% service level has been maintained.

Figure 25C shows a simulation of demand with replenishment quantity of 2 and a lead time of one period. A 94% service level is maintained.

requirements for dependent demand items

The bulk of gross requirement statements within MATERIAL REQUIREMENTS PLANNING belong in this category. These are gross requirements for all of the component items (subassemblies, component parts, and raw materials) that are calculated in the material requirements planning process or "explosion".

The gross requirements for a given component item are directly derived from the "planned orders" quantities of all items on the next higher level that use this component item (see "The Requirements 'Explosion' "). A dependent demand requirement arises only when a "parent" item on the next higher level is to be produced. The requirement equals planned consumption. Thus raw material is "consumed" when an order for a part is put into production, and a part is "consumed" when an assembly is made. Figure 26 shows how the gross requirement for an item common to several "parents" is determined.

Period	1	2	3	4	5	6
Product X Reqmt.	0	24	0	24	0	24
Subassembly Y Reqmt.	16	0	0	16	0	0
Total Reqmt. Item 2	16	24	0	40	0	24

Figure 26. Dependent demand requirements represent the sum of an item's consumption by orders for higher-level items

recording requirements data

There are two general methods of recording gross requirements data in the system.

Requirements data can be stated by *date/quantity*. Here a variable number of requirement segments are held for each item, identified by both date and quantity required (Figure 27A).

Requirements data can also be summarized by the system into *time periods* or "buckets" (Figure 27B). These extend as a series of fields throughout the whole of the materials planning horizon. The length of these periods is usually a week, or five shop calendar days, and sometimes one day.

The period date can readily be inferred from its relative position and does not have to be carried in the record itself.

Planning can be improved and inventory investment reduced if the period length is one day. The reason is illustrated in Figure 27C.

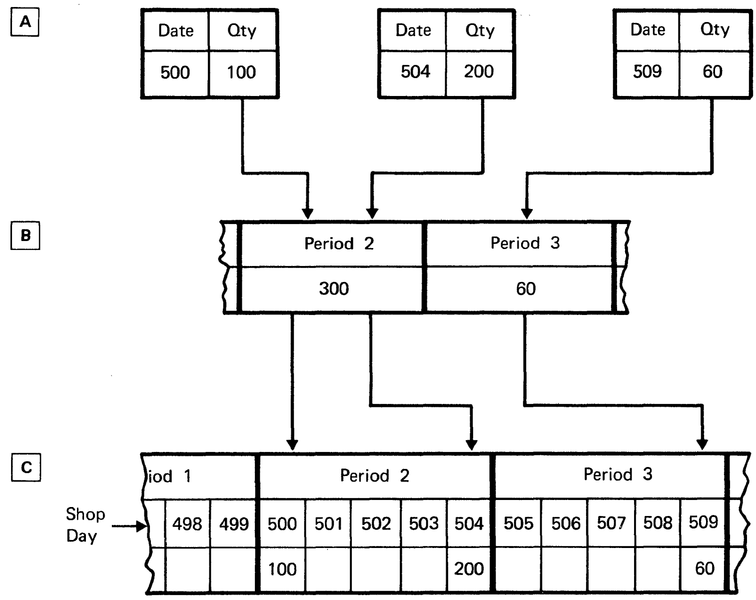


Figure 27. Retaining requirements in one-day time buckets can reduce inventory

If the two requirements are summarized in a period length of one week, the requirement sum will be 300. The problem now becomes when to specify delivery. If date 500 (first day of period) is chosen, 200 units will be carried in inventory for four days. If date 504 (last day of period) is chosen, a material shortage of 100 will occur. If the midpoint of the period is chosen (502), the shortage of two days will have to be made up by expediting. Moving all the requirements into the last day of period 1 would eliminate any shortage but would raise inventory. In addition, always specifying period beginning or ending dates may also create uneven loads on Receiving, Inspection, and Stores.

Within the inventory record, the requirements may, if desired, be stored in only one series of fields, in which case requirement sources are summarized together by period, or they may be held separately (Figure 28). It is necessary to hold separate requirements records for both dependent demand and demand from miscellaneous external sources, in order to process "net changes".

Period	1	2	3	4	5	6
Final Assembly Schedule	0	24	0	24	0	24
Miscellaneous Requirements	1	1	1	1	1	1
Dependent Demand			5			5
GROSS REQUIREMENTS	1	25	6	25	1	30

Figure 28. The various sources of requirements are held in separate fields. When summarized, they form gross requirements

Net requirements

After gross requirements have been determined and summarized, net requirements are automatically calculated for each item. The object of this calculation is to establish whether or not the gross requirements are covered (matched) by available inventory. Available inventory is defined as the quantity on hand plus the quantity on order, minus safety stock if any.

available inventory

The following elements are taken into account when determining available inventory:

- *On-hand balance* – the items physically present in their designated storage location(s). Items at Inspection or Receiving are normally considered to be still on order and are therefore not considered part of the on-hand balance.
- *Released orders* – those orders that have been released to a supplier or the shop floor. A shop order is considered released when instructions have been issued to create shop paperwork. A purchase order is considered released when the requisition is placed in the Buyer's Action File (see *Chapter 7, Order Release*). A released order is considered an addition to inventory on the date of expected delivery.
- *Allocated inventory* – quantities set aside (on the record) for use in a released shop order for a higher-level item, but not yet withdrawn from stock. This category exists because of the time lag between order release and actual stock withdrawal. Allocations are considered firm commitments that cannot be automatically altered. The inventory administrator may override this commitment.
- *Safety stock* is a reservation to absorb possible fluctuations in demand. Since it must be reserved until the time of need, it is not available for other use and is subtracted from available inventory.

Gross requirements are, of course, claims against available inventory. It should be noted that quantities previously allocated are part of the gross requirements quantities. In the calculation of available inventory, they are taken into account merely for their *timing.* Both "gross requirements" and "allocated" quantities are reduced, along with the on-hand quantity, at the time of issue of the item. An exception is an unscheduled issue, such as for plant maintenance purposes, that reduces only the on-hand quantity.

allocated stock

The association between a demand and the source covering the demand, called "allocation", can be recorded at either of two times:

- *During order release* (for details, see *Chapter 7, Order Release*). The quantity represented as a *firm allocation* will not be shifted by the system to other orders, even if they have a higher priority, without direct intervention of the inventory administrator.

  For components not required until some later operation, the allocation is handled in such a way that it is reflected as a future firm commitment. Allocations are therefore recorded by time period.

- *During requirements planning,* when a planned order is created (or modified). For items with requirements *pegged* to specific orders (see "Pegged Requirements") this is considered a *preliminary allocation.*

  Allocations for items with a *pegged item code* are held in individual segments (see *System Date Base*). As long as the order is in "planned" status, the system can shift preliminary allocations to other orders.

effect of multiple stock locations on availability

The inventory of an item may be held in more than one location for reasons of:

Economy – to shorten the distance between the storeroom and points of use

Control – because of difference in usage, such as production and service parts stores

Service – to reduce the lead time between customer demand and actual shipment, as in the case of branch warehouses

The way multiple storage locations affect availability of inventory for purposes of net requirements calculation depends on the degree of freedom of movement between these locations.

- *Complete freedom* of movement normally exists between different storage locations in the same plant. In this case inventory in all of the locations can be considered available.

- *No freedom* of movement between locations means that demand data and safety stock (where applicable) must be maintained for each location. An example would be a widely dispersed multiplant situation. Figure 29 illustrates the effect of degree of freedom on safety stock.
- *Partial freedom* of movement means that inventory maintained in one location can occasionally be used to solve an emergency in another.

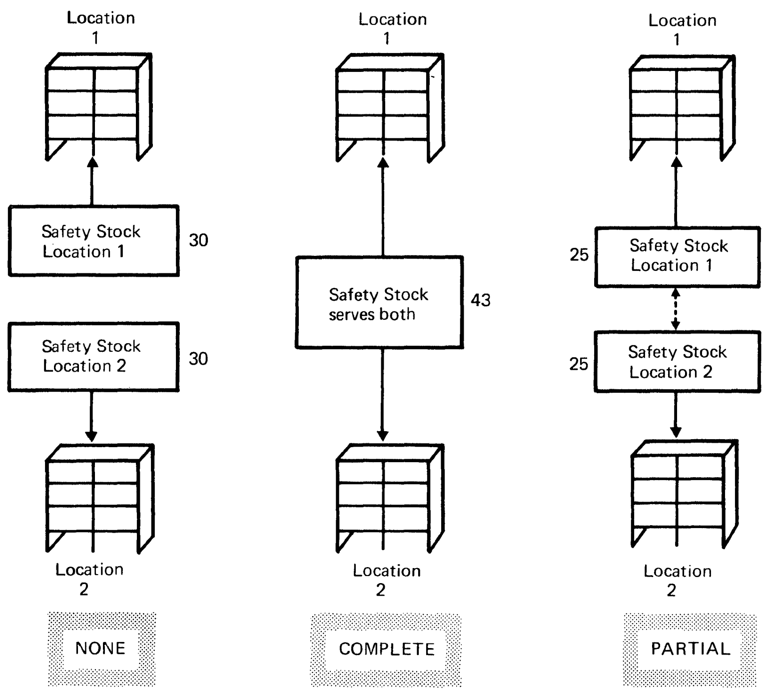


Figure 29. The amount of safety stock maintained at each location depends on the degree of freedom of stock movement between locations

unplanned excess issues and floor stock

Inventory which is already issued to the factory but which is in excess of actual requirements may be considered as available inventory and used in calculating net requirements. This can result from the following situations:

- Issuing quantities that are greater than immediate requirements, such as a reel of wire when the requirement is only fifty feet, or ten feet of bar stock when six is required, because six-foot pieces are not available. This is called an "unplanned excess issue".
- Many small parts that are used repeatedly are stored on the plant floor in the assembly areas in which they are used. These items are not requisitioned for each shop order but are issued in bulk upon request from the floor. This is called "floor stock".

Unplanned Excess Issues. When the requisition is filled, the employee drawing the stock indicates the actual amount issued. The system sets up a temporary storage location for the work center or department to which the item is issued. Future requisitions for that item and department are first filled out of this location. This will be indicated on the Requisition Action File prepared in ORDER RELEASE. The inventory stored in these locations is considered available for netting purposes.

Floor Stock. Inventory is sometimes issued to assembly areas in bulk. *Chapter 8, Plant Monitoring and Control* discusses how such requisitions are communicated.

From an inventory management standpoint, these types of items can be considered, and treated, as independent demand items. The request for issue of the bulk quantity is the demand figure used to forecast future requirements and safety stock. High-cost items in this category are not so treated. The lot-sizing rules, however, must take into account the normal issue quantity. Inventory stored on the floor is considered available in the net requirements calculation.

The system keeps track of how much material is on the floor at any time by offsetting known requirements against previous issues to the shop.

calculating net requirements

Figure 30 illustrates the calculation of net requirements. The requirements in periods 6 through 9 are not covered by on-hand inventory or released orders. Therefore, planned orders must be developed to cover these requirements. Determining the size and release date of the planned orders is discussed under "Determining Order Size" and "Scheduling Order Release".

Period		1	2	3	4	5	6	7	8	9
On Hand	50									
Safety Stock	20									
Released Orders				65						
Gross Requirements		5	0	40	25	0	20	15	0	10
Allocated		15	0	10	0	0	0	0	0	0
Available Inventory	30	10	10	25	0	0	0	0	0	0
Net Requirements		0	0	0	0	0	20	15	0	10

Figure 30. Example of the calculation of net requirements

Safety stock and safety lead time

Safety stock is generally carried for inventory items with independent demand. It may also be carried for certain selected dependent demand items, as an exception to the general rule. For these items, which normally do not require safety stock since their demand is *calculated* rather than forecast, so-called safety lead time is sometimes used. It serves basically the same purpose as safety stock.

safety stock for independent demand items

Figure 31 shows how safety stock for independent demand items is utilized. Starting from point 1 on the chart, inventory is reduced gradually until it reaches a level called "order point". At this time an order is released (see previous discussion of time-phased "order points"). Inventory continues to be depleted until, at point 2, the order quantity is received. However, if inventory is depleted at a higher than average rate, some of the safety stock is utilized (point 3). It is at this point, just before the receipt of the replenishment order, that there is the greatest chance of stockout.

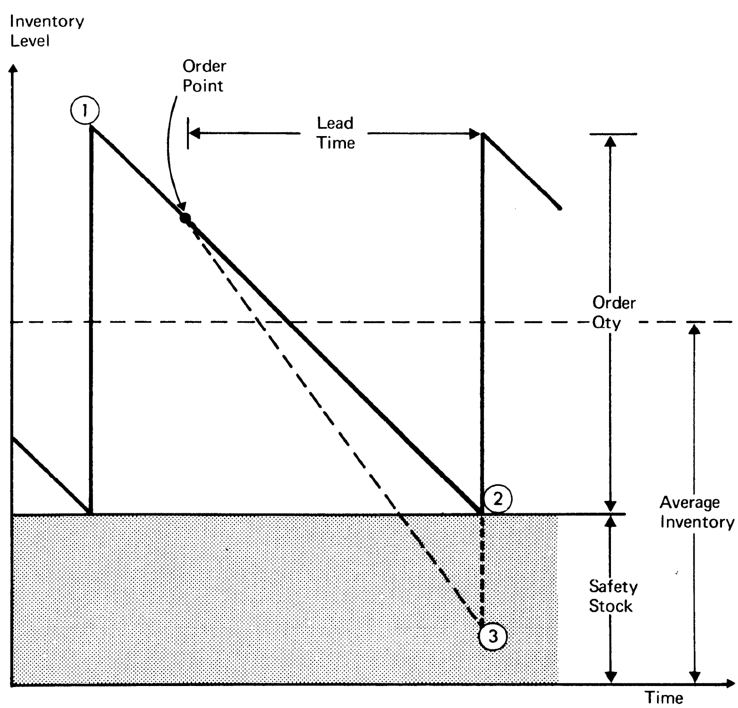


Figure 31. Safety stock is required to absorb a higher than average rate of demand during inventory replenishment

The line from point 1 to point 2 represents an *average* depletion rate. Therefore, at the time of receipt, safety stock will be utilized approximately 50% of the time. Safety stock can be thought of as a buffer used to absorb fluctuations in usage (or demand) during replenishment lead time.

The amount of safety stock is based on the size of historical forecast error during the lead time to replenish inventory. The principle on which the calculation is based is illustrated in Figure 32.

In situation A, actual demand does not vary significantly from the forecast. If the forecast amount were on hand at the beginning of each new period, very few stockouts would occur. The example shows that a total of 40 could not be shipped on time.

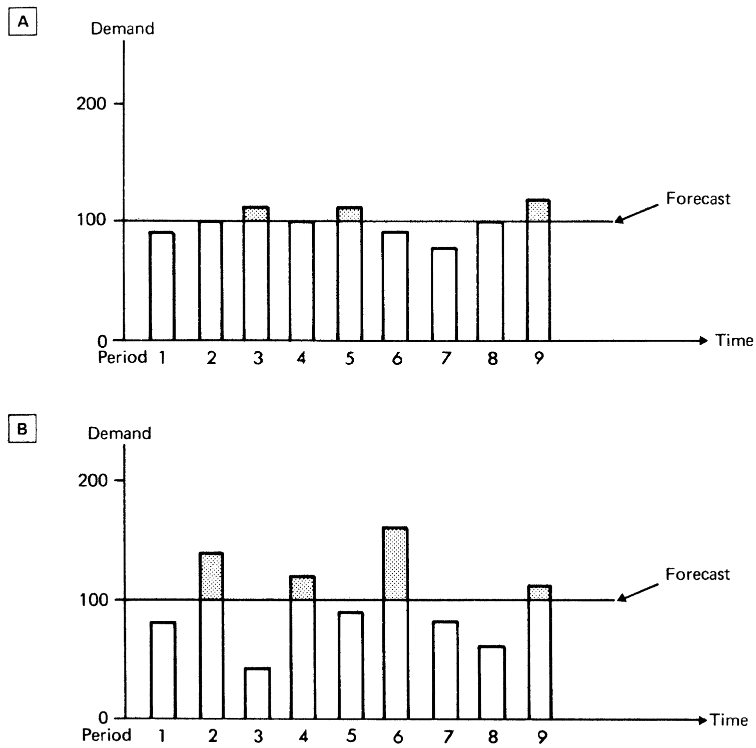


Figure 32. The more the actual demand varies from the forecast, as in situation B, the more safety stock has to be maintained to absorb the large fluctuations

In situation B, actual demand varies significantly from the forecast. If only the forecast amount were on hand at the beginning of each period, four stockouts would occur, with total lost sales of 130 pieces. In this case, much higher safety stock has to be maintained if the high peaks in demand are to be absorbed.

The procedures outlined in *Chapter 3, Forecasting* calculate the amount of forecast error. This is used, together with a factor called "service level", to determine the level of safety stock. The service level is expressed as the percentage of time that demand is to be met on request, and it is usually between 80% and 98%. *The larger the forecast error and service level, the larger the safety stock and consequently the higher the level of inventory.*

calculating safety stock

Safety stock may be designated in a number of ways:

- A fixed quantity
- A fixed amount of time – say 20 days multiplied by the average demand per day
- A fixed percentage of average demand during the replenishment lead time (for example, if average demand through lead time is 400 and the safety percentage is 20%, safety stock will be 80 units)
- An amount based on the deviation of actual demand from the forecast demand

The disadvantage of methods such as specifying a fixed quantity, time, or percentage is that they can lead to either excess inventory or stockouts. This is because they do not recognize that safety stocks should vary for each item.

fluctuation from forecast

INVENTORY PLANNING AND CONTROL calculates safety stock based on the amount of fluctuation from forecast (forecast error) for each individual item, and a management-specified service level indicating how frequently stockouts will be permitted to occur.

Figure 33 shows how actual demand may be distributed around a forecast. The distance from a demand point to the forecast line is called a forecast error. Forecast error in this case is assumed to be normally distributed (see *Chapter 3, Forecasting*). In the examples shown, the forecast error for B is much greater than for A for the same forecast of 100 units per period. This means that B would carry a larger safety stock than A, although the average demand is the same.

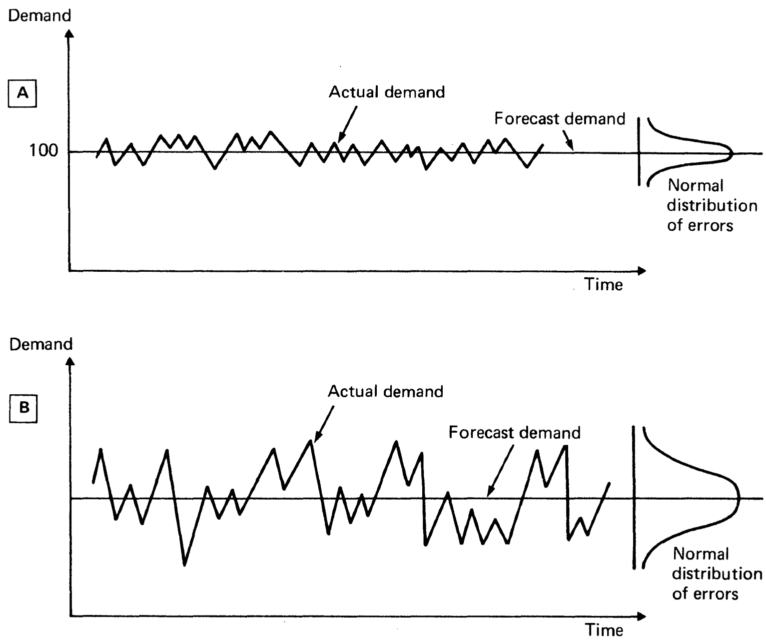


Figure 33. The system maintains a measure of average forecast error

FORECASTING measures the average size of the error. This measure is called the "mean absolute deviation of forecast error" (MAD). The more forecast error (that is, the wider the fluctuations in demand), the larger the MAD. Measured in units, MAD can be used statistically to make a prediction such as: "95% of the time, demand within a period will be between 80 and 120 units."

service level

The "service level" is the percentage of demand to be filled routinely from on-hand inventory.

$$\text{service level} = \frac{\text{shipments}}{\text{demand}} \times 100$$

Management can specify a different service level percentage for each item. This is usually based on the importance of the item. For example, a service level of 98% may be maintained on an item that contributes high volume and high profit, while a service level of 90% may be assigned to a low-profit, low-volume item.

Safety stock is calculated by multiplying a factor representing the service levels times MAD. For example, if MAD through replenishment lead time is 10 units and a service level of 98% is required, then approximately 3 MADs or 30 units must be kept as safety stock.

The higher the level of service, the more safety stock is required (Figure 34). As the service level approaches 100%, the amount of investment required increases very rapidly.

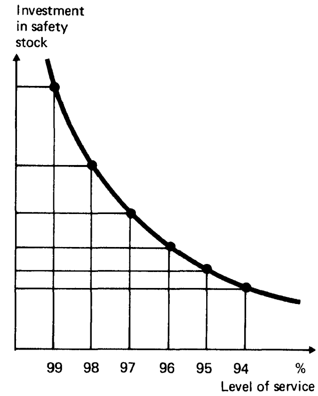


Figure 34. As the service level percentage increases, inventory investment increases dramatically

Management can manipulate the amount of money invested in independent demand item inventory by varying the service level. A curve, such as shown in Figure 34, can be developed for each item or class of items. Management can then see in advance how much money would be released if the service level percentage were to be lowered, or what additional investment would be required to increase customer service.

If the unmet demand represents a lost sale, the system can prepare another curve or table showing lost volume or profit at each service level (Figure 35).

	Product Group A		Product Group B	
Service Level	Lost Sales	Lost Profit	Lost Sales	Lost Profit
99	5,000	1,000	20,000	6,00
95	25,000	5,000	90,000	27,00
90	43,000	8,600	150,000	45,00
85	68,000	13,600	200,000	60,00
80	80,000	16,000	240,000	72,00
75	90,000	18,000	270,000	87,0

Figure 35. The service level can also be related to lost volume and profit

The replenishment order quantity also has an effect on the amount of safety stock carried. Exposure to stockout is greatest at time of replenishment. The more exposures, therefore, the larger the safety stock. Figure 36 illustrates this. In the first case, the order or lot size results in only two replenishment orders per year. In the other, the item is ordered six times per year. This will lower inventory investment. Ordering costs, however, will go up and also the level of safety stock.

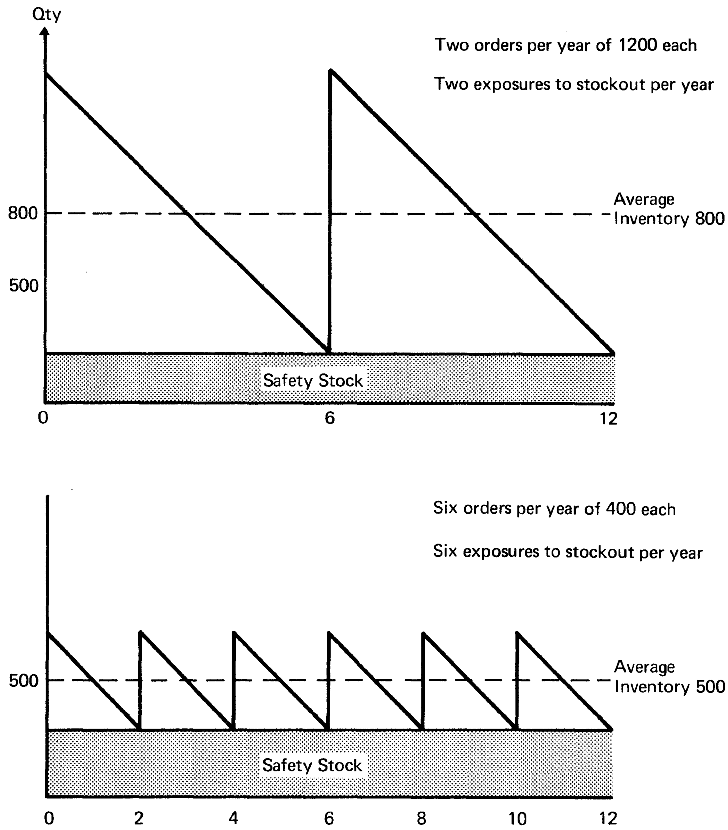


Figure 36. Effect of order size on safety stock

safety lead time for independent demand items

For various reasons, neither manufacturing nor suppliers always meet lead time commitments. The system can measure the deviation of actual delivery from specified delivery. Lead time deviation can be assumed to be normally distributed and a service level can be specified to satisfy this deviation (Figure 37). Care must be taken that deviations resulting from rush or deferred orders are not included in the calculation of the MAD of delivery lead time.

safety stock for dependent demand items

Raw material, component parts, and subassemblies have demand that is directly dependent on the planned production of their "parent" items. Dependent demand items are under the control of MATERIAL REQUIREMENTS PLANNING, which calculates this demand precisely, as to both quantity and timing. Under such conditions, safety stock at the component item level is, by definition, not required.

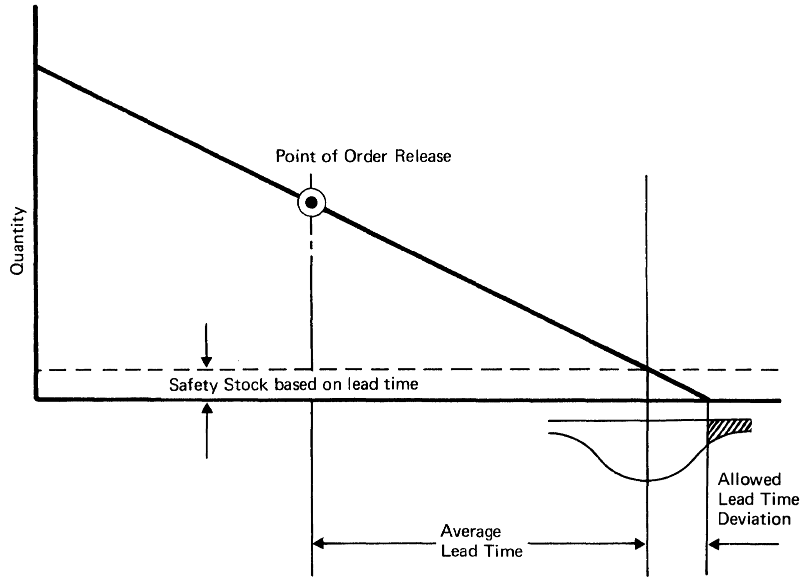


Figure 37. Delivery variations can be measured statistically and a safety stock allowance based on service level and the MAD of lead time can be established

This does not mean that safety stock cannot be used in MATERIAL REQUIREMENTS PLANNING – the system can incorporate safety stock for any item specified by management.

But if safety stock is to be used, it is best to apply it at the *end item level*, not the component level. Safety stock will thus be included in the statement of requirements represented by the master production schedule, and MATERIAL REQUIREMENTS PLANNING will automatically plan the quantities of the respective component items in *matched sets*. Safety stock quantities calculated at the level of individual component items would not match each other well, and thus would make it impossible to produce a desired extra quantity of higher-level items without excessive inventory.

An exception to this general rule may be made in the case of selected component items (such as complex castings) that combine a high incidence of scrap with very long lead time, or items (such as certain assembled purchased items) that have had erratic supplier performance as to quality.

Another exception is the treatment of certain component items as if they were subject to independent demand. Minor parts such as bolts, nuts, screws, etc., are part of the bill of material, and their requirements are generally calculated despite their minor nature. Companies with large numbers of such parts may, however, choose to treat them as independent demand items. The forecast is then based on historical usage. This approach is successful if the part is common to a wide variety of products and if, as a consequence, its demand pattern is not erratic. High service level percentages must be maintained to avoid stockout. Even though this requires large safety stocks, the impact on inventory is usually not significant because of the low cost of these types of items.

using independent demand safety stock for production

Sometimes independent demand safety stock is used for current production. In many companies, inventory maintained for service parts is separated physically from that used for production. One of the major reasons for this is to prevent unauthorized withdrawal from one inventory to service the other.

In COPICS, inventory set aside for independent (customer) demand may be withdrawn for dependent production demand if authorized by the inventory administrator. Because the system maintains separate control records for each source of demand and plans all withdrawals, physical separation of stock is no longer necessary.

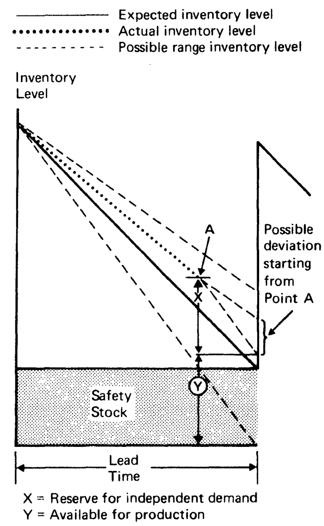


Figure 38. As delivery approaches, the expected demand deviation can be recalculated

Transfer of stock can be automatic. Safety stock is used to absorb possible fluctuations in demand between the time of order release and delivery (Figure 38). During replenishment lead time the rate of demand can be analyzed to see whether some of the safety stock can be released for use in production. To determine the amount that can be released, the expected deviation is recalculated starting from the current date (A in Figure 38). The amount up to the lowest expected level can be safely released for production. This calculation can be performed automatically for high-cost items or can be requested by the inventory administrator when critical situations arise.

safety stock for product options

At the end item level, safety stock is, in effect, planned when forecasting demand for product variations (see *Chapter 4, Master Production Schedule Planning*). Product options and variations are handled in a similar way to finished products; that is, a forecast model is developed to predict the percentage of time the variation or option will appear on the product. A percentage, rather than a quantity, is forecast in order to generate option requirements in proportion to finished product requirements.

For example, suppose that there were two variations, A and B. The forecast is for A to be used 40% of the time and B 60%. If the master production schedule calls for 100 products, it can be estimated that 40 A's and 60 B's must be made available in order to meet the schedule. In any one planning period, however, the mix of actual orders can be quite different; it is possible in one period, for instance, for orders to require 45 A's, and 55 B's.

The system could add 10% for protection and plan 44 A's and 66 B's. There will be a total of 10 units not used (that is, safety stock), but there is no way of knowing in advance which ones. Alternatively, a technique called the "binomial theorem" makes it possible to compute quite accurately the standard deviation of the number of each option that will be required.

Thus, one could add two or three standard deviations for protection against variations in the order mix. This adds to the inventory, but protects the ability to fill future orders.

safety lead time

Safety stock is normally not required when demand is solely dependent. The situation is illustrated in Figure 39. Only when an assembly order is placed for finished product A is demand for component C generated. The demand for component C is very discontinuous. Maintaining a safety stock of, say, 20, when faced with periodic, lumpy demand of 100 does very little good. Assuming a lead time of one period to replenish, the on-hand quantity of C is kept unnecessarily high until the next shop order for A is generated.

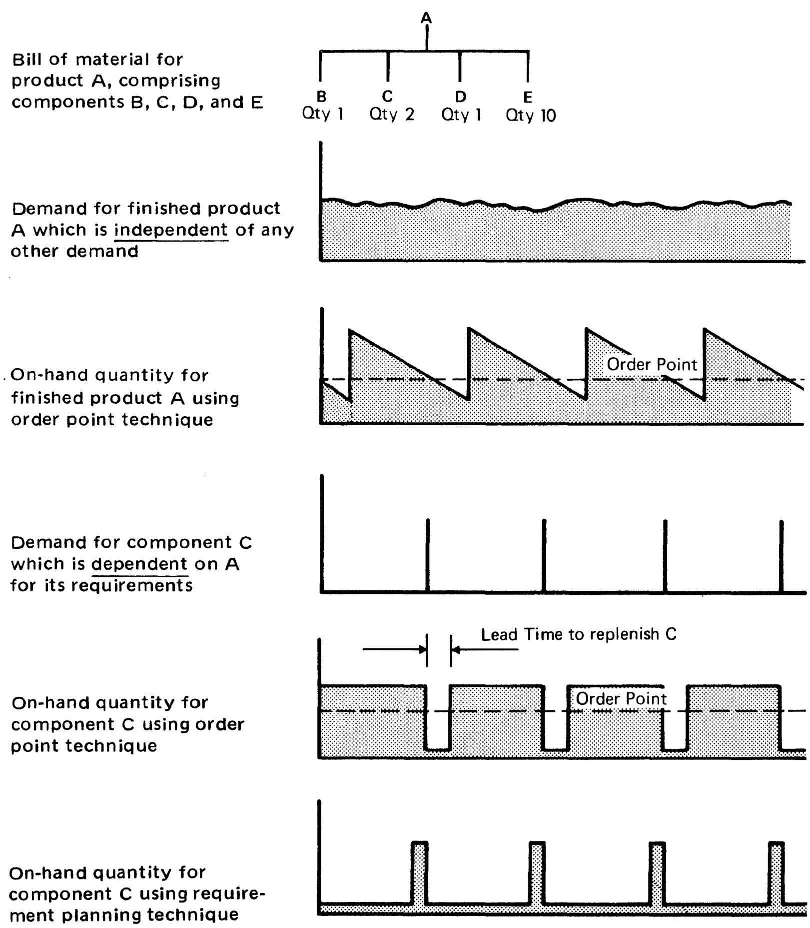


Figure 39. The objective is to minimize inventory by scheduling the delivery of components so that they arrive just before they are required

The ideal situation is represented in the bottom graph of Figure 39. The object is to schedule the production of component C so that it arrives just before being needed in assembling finished product A. In this case, inventory of C is carried for only a short length of time. This result is exactly what MATERIAL REQUIREMENTS PLANNING is designed to accomplish. It times the delivery of lower-level components so that inventory will be at a minimum. If the component is delivered on time, no safety stock is required and no stockout will occur.

Exact timing of the replenishment order is a major objective of MATERIAL REQUIREMENTS PLANNING. However, because deliveries from suppliers or the company's own shop are not always made according to promise, a "safety lead time" can be allowed (see Figure 40). This is a slight forward adjustment to the component order due date. Safety lead time for manufactured parts, if used at all, should be very short and, above all, *uniform* for all classes of parts, as otherwise relative shop order priorities become unrealistic.

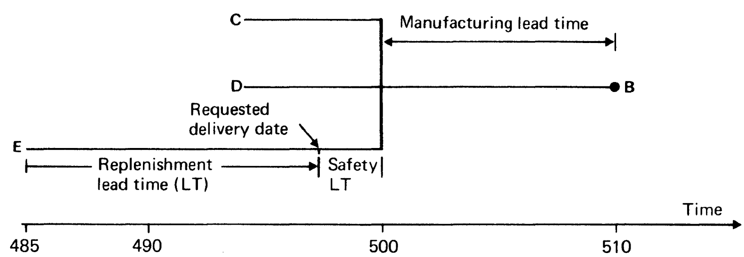


Figure 40. If the requested delivery date is earlier than needed, the number of days allowed is called the "safety lead time"

It should be kept in mind that MATERIAL REQUIREMENTS PLANNING is designed to establish component order due dates to correspond to the exact date of need – when assembly is scheduled to begin. If safety lead times are used for manufactured components, order due dates will precede the date of need. Shop personnel will soon learn that the due dates are not in concert with the real need.

As long as the safety lead times are slight and uniform, the relative shop order priorities are not affected. If, however, the safety lead times are allowed to vary (for example, one period for "A" items, two periods for "B" items, and three periods for "C" items), the whole scheme of formal shop order priorities is destroyed and shop personnel lose confidence in the system.

This will be the result of relative priorities having become distorted. Suppose the date of need for an "A" item is period 100 and for a "C" item, period 101. The former would be scheduled for completion in period 99 and the latter in period 98. Thus the item that will actually be needed earlier is scheduled for *later* completion. If production runs behind schedule, or if these two items contend for capacity at the same bottleneck machine, the foremen and expediters will disregard (and properly so) the priorities set by the system and will work on the item that will in reality be needed earlier.

Safety lead times for *manufactured* component items should be used with caution. There is no objection to using them for *purchased* items, provided that planning lead times, and inventories, are not significantly increased.

Determining order size

The system covers net requirements by creating *planned orders.* The size of the order may be identical to the net requirement for a given period, or may represent an economical order quantity. The planned orders, when eventually released, are of three basic types:

- *Shop orders* for finished products, subassemblies, and components manufactured internally
- *Purchase orders* for components and raw materials procured from an outside supplier
- *Interplant orders* for items manufactured and supplied by another plant

Some items may be either purchased or manufactured. The system maintains separate sets of data concerning order size to facilitate the selection of the source.

A planned order does not become a commitment until it is released as a shop or purchase order. However, it is used to explode and schedule lower-level component requirements (and to plan future capacity requirements) and must therefore be a true reflection of what will eventually happen, unless requirements change significantly.

discrete order quantities

Discrete order quantities, which correspond to net requirements for each period, result in the lowest possible inventory. They are generally used for very expensive items, for large assemblies, or for items supplied or manufactured on a continuous basis. This policy, implemented by coding the product definition record accordingly, simply means that orders are planned in the exact quantities and timing indicated on the net requirements schedule (Figure 41).

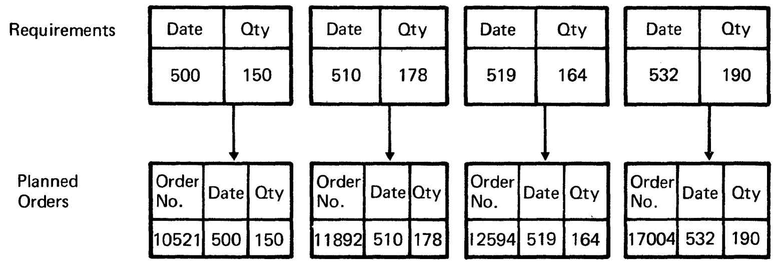


Figure 41. Ordering discrete quantities results in placing an order for the exact net requirements for a period

economical order quantities

Many items, however, are not ordered on a discrete basis. Instead, an order size is determined which balances the cost of acquisition with the cost of carrying the item in inventory. The function of determining order size is called "lot sizing".

The size of the order has a significant impact on the average inventory level (Figure 42). Through control of the order size policy, management can therefore regulate the level of inventory. Control is exercised by changing either of the two cost elements that determine order size: inventory carrying cost and order cost.

The theory of economical lot sizing is presented in Figure 43. As the order quantity is increased, the average level of inventory rises. The carrying cost therefore increases at a constant rate. As order size increases, acquisition costs such as setup can be spread over more units, and the unit cost therefore decreases. The total cost line in Figure 43 represents the sum of the two lines. The point of minimum cost indicates the most economical order quantity.

The *carrying cost* is usually expressed as a percentage of the average inventory value. Typical values for manufacturing companies range between 15% and 35% per year. Although many companies employ one rate for all items, the percentage can vary by item or by item class. The carrying cost percentage is derived from a number of elements, including the cost of money, insurance, taxes, obsolescence, and storage.

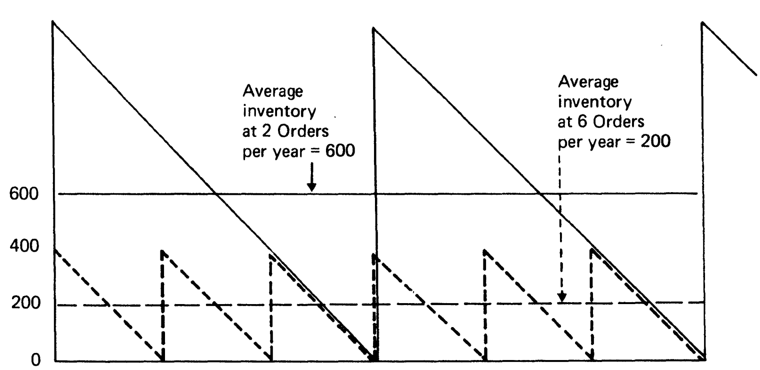


Figure 42. Order size has a significant impact on average inventory level

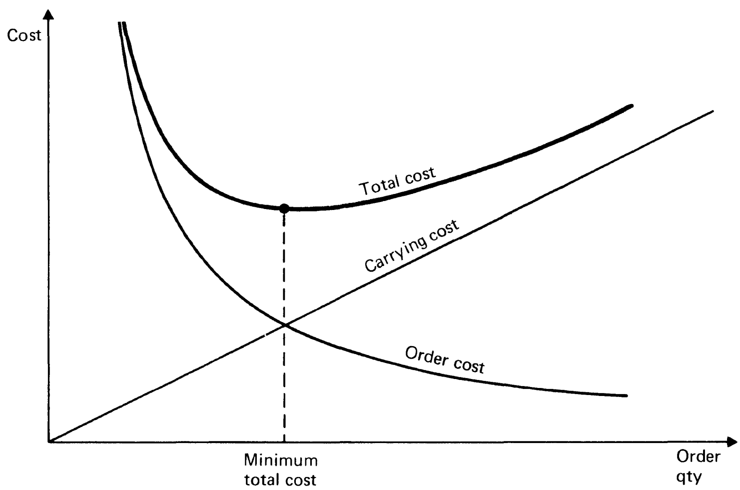


Figure 43. Analysis of the two major cost elements, order and carrying costs, determines the order quantity that will result in the lowest total cost

Purchase order costs can be calculated by dividing the total number of purchase orders into the sum of the costs from Purchasing, Accounts Payable, Receiving, and Receiving Inspection, plus a share of Stores and Materials Handling costs.

Most companies, however, can absorb some fluctuation in purchasing load, and the cost per incremental purchase order is not considered a factor.

quantity discounts

Quantity discounts have the principal effect on the lot sizing of purchased items. Quantity discounts can be reduced to a price that applies between a range of quantities. The effect on determining an economical order quantity is illustrated in Figure 44. The system calculates a cost curve for each price range and chooses the price/quantity yielding the lowest cost.

Shipping charges per unit can sometimes be reduced if an entire truckload is shipped. The unit cost difference between a full and partial truckload shipment can be calculated and supplied to the system in the form of a price break. Variable shipping costs can thus be considered in the calculation of economical purchase order quantities.

Shop order costs also contain some elements of handling expense, such as generating shop paperwork and handling the receipt in stores. By far the most significant, however, are the sum of setup and teardown costs for each operation. Both handling and setup costs can be quite accurately calculated from data in the Manufacturing Routing. The sum of these cost elements is carried in each inventory segment of the product definition data base.

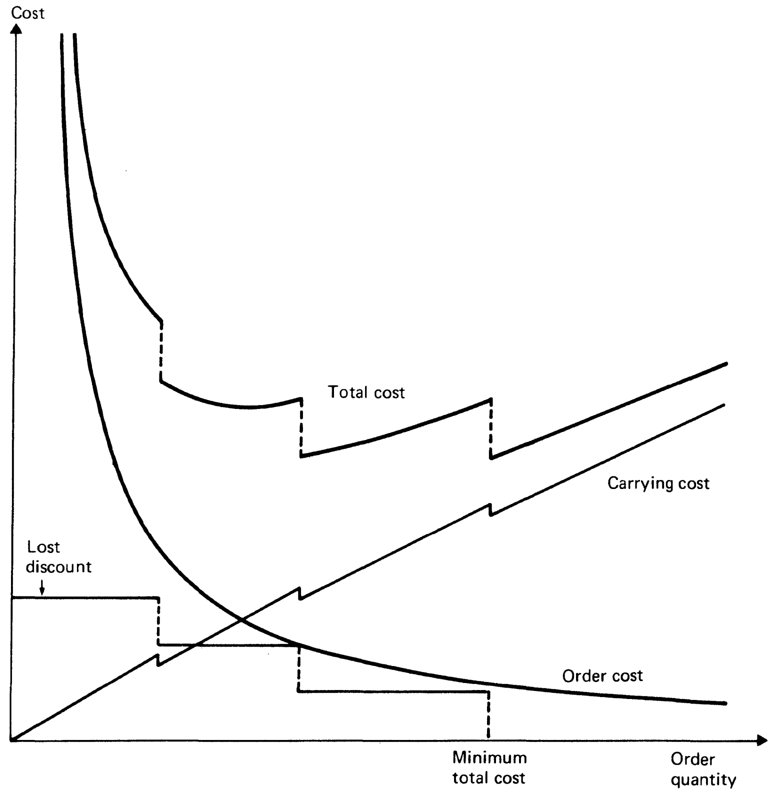


Figure 44. Quantity discounts can be considered in an EOQ calculation

$$\text{EOQ} = \sqrt{\frac{2 \times \text{Order Cost} \times \text{Annual Usage}}{\text{Inv. Carrying Rate} \times \text{Unit Cost}}}$$

$$= \sqrt{\frac{2 \times 100 \times 2000}{0.20 \times 20}} = 316$$

Figure 45. The basic EOQ model is used when usage is fairly constant

Many techniques are used for calculating economical order quantity (EOQ). Two that have found wide acceptance in manufacturing are:

- *Basic EOQ model,* which is very simple to use and works quite well for items with fairly steady demand.
- *Part-period balancing,* also known as "least total cost", which gives an improved solution when the demand is not constant (as in the case of many components).

Basic EOQ Model. This model is shown in Figure 45.

$$\text{EOQ} = \sqrt{\frac{2 \times \text{Order Cost}}{\text{Inventory Carrying Rate}}} \times \sqrt{\frac{\text{Annual Usage}}{\text{Unit Cost}}}$$

OR

$$\text{EOQ} = K \times \sqrt{\frac{\text{Annual Usage}}{\text{Unit Cost}}}$$

Figure 46. The level of inventory can be altered by varying a constant

Another way of looking at the formula is shown in Figure 46. The cost portions that remain fairly constant for an item can be separated and summarized in a constant K. To control the level of inventory resulting from lot sizing, the constant K can be varied by applying a percentage change factor. This approach is sometimes used for groups or families of parts. The system can accurately estimate in advance the impact on inventory and cost.

The basic EOQ formula assumes that annual usage is known and that inventory depletion is gradual. In manufacturing, this is often not true. Furthermore, it ignores the *timing* of requirements. Therefore, the standard EOQ approach can be used with confidence only for items with constant demand, for service parts, and for certain items held in branch warehouses.

Part-Period Balancing. This technique, also known as "least total cost", gives better results for most items required in manufacturing, where the demand fluctuates and may be discontinuous. Part-period balancing incorporates a "look-ahead, look-back" feature, and is described in Figure 48.

limitations imposed on order size

The calculated economical order quantity does not take into account certain practical limitations that affect actual order size. Limitations that are applied each time an order size is calculated are stored on the inventory segment of the product definition record. Some of the more common order size limitations are minimum (floor) and maximum (ceiling) quantities, package or container size, storage space, tool life, joint replenishment considerations, and rounding or multiple factors.

Lot size restrictions may be used individually or in conjunction with one another. The effect of some of these order size limitations is illustrated in Figure 47. The inventory administrator has the ability to code a part for individual review when he wishes to restrict normal lot-sizing decisions made by the system.

Order Size Limitation Examples	Requirements	0	85	220	155	145	95	145	110	210	130
	Planned Orders Part-Period Bal.		305		395			255		370	
1	Rounding Factor (10)		310		390			260		370	
2	Maximum (350)		305		350		300			350	
3	Minimum (300)		305		395			300		325	
4	Pack Size (50)		350		350			300		350	
5	Maximum (300) + Pack Size (100)		400		300			300		400	

Figure 47. The effect of different order size limitations is to modify the calculated EOQ to reflect practical considerations

PART-PERIOD BALANCING

A "part-period" is one part held in inventory one period. The total number of part-periods, then, is the number of parts held in inventory multiplied by the number of periods held.

Each part-period incurs a certain carrying cost. Thus, whether three units are held for two periods or vice versa, the number of part-periods is six and the carrying cost is six times that for one part-period.

When the accumulated carrying cost exceeds the order costs, an order is planned. To facilitate calculation, an economic part-period is calculated. This is the point in time where accumulated part-period costs exceed the cost of an order. The due date of the order is the earliest period's requirement included in the calculation.

For example,

Item Cost	=	10.00
Order Cost	=	60.00
Carrying Rate (24%/Yr)	=	2% per period

$$\text{Economic Part-Periods} = \frac{\text{Order Cost}}{\text{Inventory Carrying Cost}} = \frac{60}{0.02 \times 10} = 300 \text{ Part-Periods}$$

Period	1	2	3	4	5	6	7	8	9
Net Requirements	0	85	220	175	145	75	145	110	210
Planned Orders		?							
Periods Carried		x 0	x 1	x 2					
Part-Period Value		0	220	350					
Cumulative PPV		0	220	570					
Planned Orders	0	305	0	?					
Periods Carried				x 0	x 1	x 2	x 3		
Part-Period Value				0	145	150	435		
Cumulative PPV				0	145	295	730		
Planned Orders	0	305	0	395	0	0	?		

In the above table, the calculation starts with the first net requirement of 85 in period 2. Any order delivered in period 2 will be immediately used for these 85 and no costs are involved. However, if the next period's requirement of 220 is included (for an order size of 305), the 220 will have to be carried for one week or 220 part-periods. Similarly, the 175 in period 4 would be carried 2 weeks and contribute a cost of 350 part-periods. At this point the cumulative value exceeds the optimum value of 300. The calculation is therefore halted, and the order size is set at the sum of requirements for all periods up to, but not including, the period causing the economic part-period quantity to be exceeded (period 4).

Another calculation is started at this point and results in an order of 395. This is continued until all requirements are satisfied.

Figure 48. Example of part-period balancing calculation (sheet 1 of 2)

Look Ahead/Look Back Feature

The planned order may be changed by the look-ahead/look-back feature. This feature prevents planning receipt of an order when a period of abnormally low demand precedes a period of high demand. The basic concept is to avoid excessive carrying costs during periods of low demand. The solution results in an order being received in a period of high demand.

Example: Economic Part-Period = 100

Period	1	2	3	4	5	6	7	8	9
Net Requirements	50	35	30	5	35	20	5	30	35
Cumulative Part-Period Value	0	35	95	110					
Normal Part-Period Balancing									
Tentative Orders Planned	115			(x)					
Part-Period Value for next Requirements				15	35				
Look-Ahead									
Final Orders Planned	120				x				

The look-ahead example illustrated attempts to move the next planned order to a period of high demand.

After an order has been tentatively planned, it "looks ahead". The cost of carrying the next period's demand with the first planned order is calculated (in the example, the demand of period 4 increases the cumulative part-period value of the first planned order by 15). This is compared with the cost of carrying the demand of the following period for one extra period (in the example, carrying demand of period 5 in an order placed for period 4 instead of period 5 increases the cumulative part-period value by 35). The approach yielding the lowest cost is chosen. Since carrying a quantity of five for three periods is cheaper than carrying 35 for one period, the quantity of five is combined with the first order.

Figure 48. Example of part-period balancing calculation (sheet 2 of 2)

In many processes, on certain types of manufacturing equipment, and on assembly lines, it may be desirable to establish a fixed output rate for an item (Figure 49).

Period	1	2	3	4	5	6	7	8
Net Requirements	25	30	35	30	40	45	35	40
Fixed Rate	35	35	35	35	35	35	35	35
Availability	10	15	15	20	15	5	5	0

Figure 49. Stabilizing component requirements to eliminate fluctuations in the production rate is another lot-sizing procedure used by the system

lot-sizing interplant orders

In the case of interplant orders, the major lot-sizing decision should be made by the plant producing the item, because this plant incurs the major order cost elements of setup and teardown (Figure 50). The plant requiring the item should supply handling cost elements and other lot size restrictions such as maximum container size, etc.

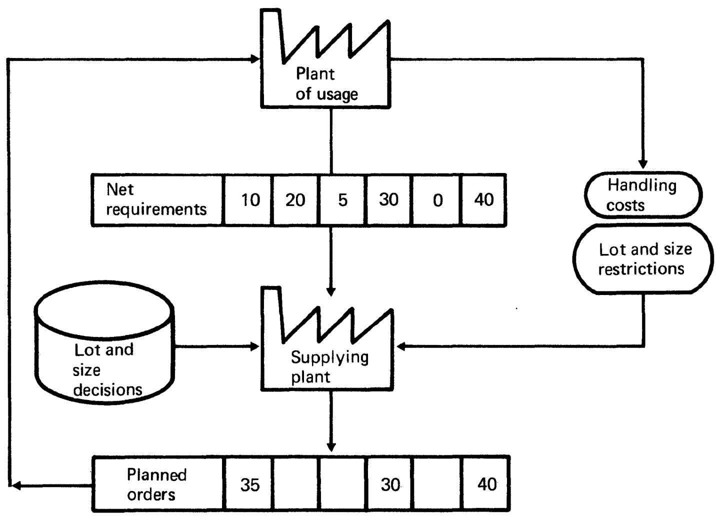


Figure 50. For interplant items the major lot-sizing decisions should be made at the plant of manufacture

scrap allowances

For manufactured items the planned lot size can be adjusted to allow for scrap. The scrap (or yield) factor (Figure 51) indicates how many parts must be started at the initial operation in order to yield the desired quantity by the final operation.

Average yield = 93 %

Mad yield = 10 %

Yield factor at 95% service level = 91 %

Planned orders before yield		100	110	125
Planned orders with yield		110	121	137

$$\text{Start quantity} = \frac{\text{Requirements}}{\text{Yield factor}}$$

Figure 51. The yield factor is used for calculating the increase in order size needed to ensure that the required quantity will be completed

If consecutive order quantities for a given item do not vary significantly from one another, the yield factor can be calculated using "exponential smoothing" (see *Chapter 3, Forecasting*). This technique will develop a *mean absolute deviation of yield* (MAD) which can be used to set the yield factor. This factor is based on the fluctuation of scrap from its historical average, and on a specified service level. Higher service levels should be used on small lot sizes because the impact of scrap on small lots tends to be more significant.

If an item is being ordered in widely varying quantities, as is particularly the case with discrete ordering, the "exponential smoothing" approach will prove unsatisfactory, as would a fixed percentage scrap allowance. This is because scrap is often primarily a function of the number of setups, rather than the quantity of parts being manufactured.

In certain manufacturing processes, especially where dies are involved, scrap tends to occur during or immediately after setup. Under such conditions, a large lot can be expected to have a smaller percentage of scrap than a small lot. For example, ten pieces may be scrapped on a lot of 200 (or 5%), and twenty on a lot of 1,000 (or 2%).

A scrap allowance formula that reduces the allowance percentage as the order quantity increases is as follows:

$$S = f\sqrt{Q}$$

where S is the scrap allowance in pieces
f is the variable factor (value normally 1)
Q is the order quantity before the allowance is added

The variable factor is specified by the inventory administrator, based on the incidence of scrap for a given item. If the value of this factor is 1, there will be a 100% scrap allowance for a one-piece order, a 1% scrap allowance for a 10,000-piece order.

Scheduling order release

The due date of the order is always the date of the first net requirement the order covers, minus an allowance, if any, for safety lead time. The next step is to determine the release date of the planned order. This is done by subtracting the purchasing or manufacturing lead time from the due date. The calculated date becomes the *planned release date* (Figure 52). The function of subtracting the lead time is called "offsetting".

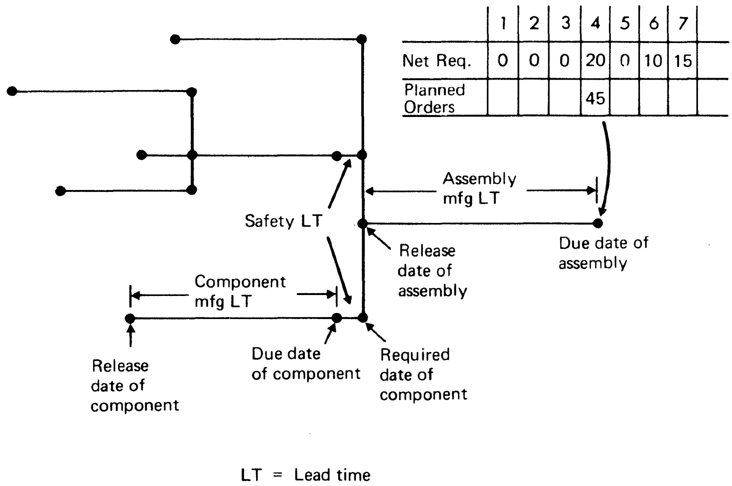


Figure 52. Lead time is subtracted from the due date to determine the release date

lead time

Whether lead times are realistic or not determines how effective the requirements planning approach will be in reducing shortages and inventory. This is because the release date of the assembly order is the basis for the due date of the components used in the assembly (see Figure 52). How important it is that lead time be realistic depends on the type of demand for the item in question.

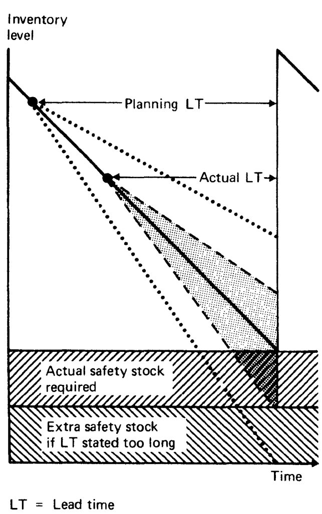


Figure 53. A planning lead time that is too long increases safety stock

One effect of inaccurate lead time for an independent demand item is shown in Figure 53. Safety stock is based on the range of possible forecast error during replenishment lead time. The longer the lead time, the larger the possible error. Therefore, if the lead time used in planning is longer than the actual lead time, safety stock will be increased to an unnecessarily high level. If the planning lead time can be shortened, inventory can be significantly reduced. If planning lead time is too short, however, the effect is to understate safety stock and therefore increase the incidence of stockouts.

For a dependent demand item, the effect of inaccurate lead times is different because safety stock is usually not maintained. However, the consequences are just as serious (Figure 54):

- *If lead time is too long,* the shop order is released to the shop too early. Manufacturing departments seldom complete the order ahead of the due date, and, as a consequence, it tends to remain on the shop floor for the planned amount of lead time. This increases work-in-process inventory, along with shop congestion and the associated problems described in *Chapter 6, Manufacturing Activity Planning.*

- *If lead time is too short,* the shop order is released too late and a lot of expediting is necessary in order to meet the due date, if it can be met at all.

If lead times for manufactured items start to increase because of overload on the plant floor, the planned lead time should not be increased. This would only compound the problem because earlier release would create more work-in-process, longer work queues in front of each work center, and even longer lead times. This is discussed in detail in *Chapter 6, Manufacturing Activity Planning.*

specifying purchasing lead time

The lead time for a purchased item is negotiated with the supplier by the buyer. Lead time considerations are discussed in *Chapter 10, Purchasing and Receiving.*

To facilitate planning to meet rush orders, vendors of critical items should be asked to quote an "emergency" lead time. Price increases or quantity limitations would probably be associated with this quote.

In certain cases, with multiple sources of supply for one item, approved suppliers may quote different lead times. For planning purposes, the longest quoted lead time will have to be utilized.

The quoted supplier lead time must be modified to allow for the time needed to process the order and the receipt within the plant (Figure 55). Included would be:

- *Review time* – an allowance for the time between release of the purchase requisition and the receipt of the order by the supplier. A code on the inventory item record would indicate the amount of buyer intervention required.
- *Receiving time* – an allowance for an average waiting time in Receiving plus an average allowance for counting and checking. This would normally be a standard allowance for all items.
- *Inspection time* – an allowance for average inspection time and inspection waiting time. It can vary by item.

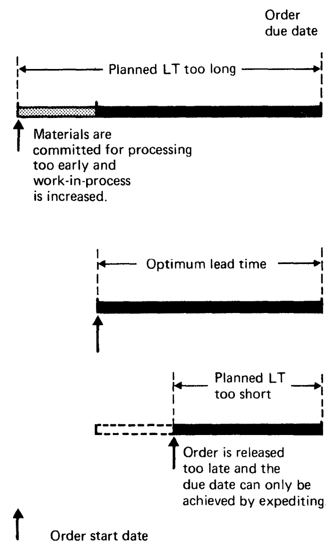


Figure 54. Inaccurate lead times for dependent demand items either increase work-in-process or cause excessive expediting

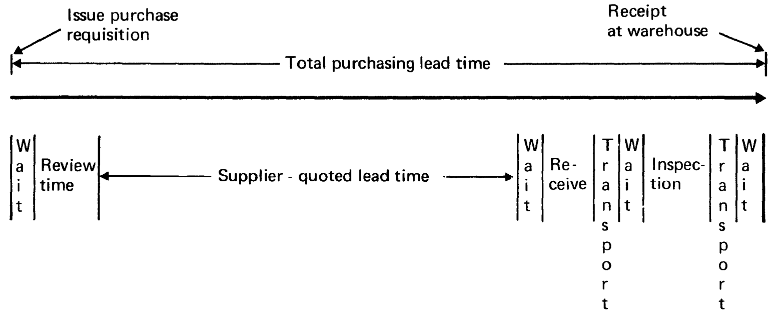


Figure 55. Allowance must be made for internal processing time when deriving purchasing lead time

calculating manufacturing lead time

MANUFACTURING ACTIVITY PLANNING develops and maintains statistics that are used to calculate the planned manufacturing lead time. Figure 56 shows the lead time elements, which are discussed in detail in *Chapter 6, Manufacturing Activity Planning.*

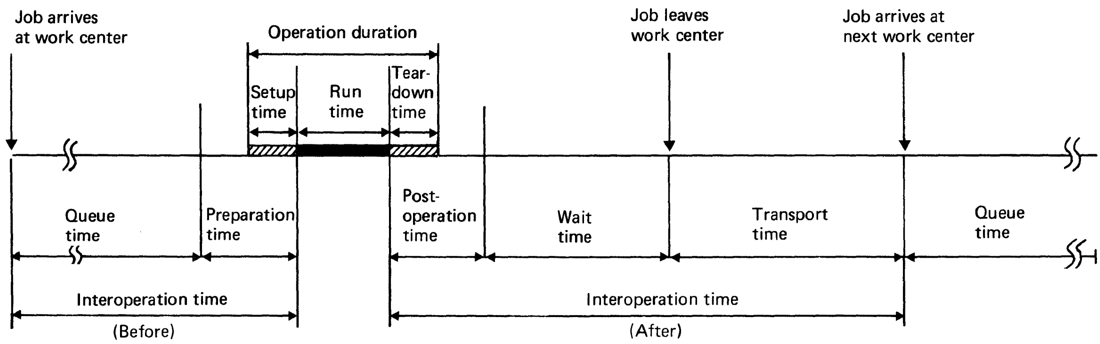


Figure 56. The various elements of manufacturing lead time can be calculated from data supplied by MANUFACTURING ACTIVITY PLANNING

The lead time elements that do not vary with the size of the order (such as queue time) are separated from run time. This simplifies the calculation of the planned order lead time, which can be performed each time an order is planned.

For low-cost, minor items, the lead time is usually calculated only once on the basis of average order sizes. In machine shops, normally only about 10% of lead time is run time spent on the machine; deviations in quantity, therefore, should not seriously affect lead time.

The release date of an assembly order is normally the required date for its component parts. In some cases, however, not all components are required at the initial assembly operation. A factor carried in the product structure record allows specified components to be offset different lengths of time from the assembly order start date (Figure 57). If manufacturing lead time is long, this approach can lead to reductions in component inventory.

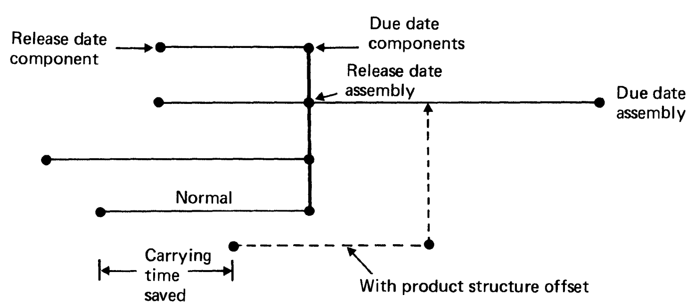


Figure 57. When all the components are not needed at the initial operation, the use of product structure offset can reduce inventory

When normal lead times are not observed, either in making customer delivery commitments, or changing the master production schedule, material requirements as well as planned order releases may fall into the past.

requirements falling into the past

Requirements falling into the past are carried in date/quantity format (see "Recording Requirements Data" under "Gross Requirements"). This will allow the system in later analysis to make adjustments on the basis of the exact number of days late.

As indicated in Figure 58A, material requirements planning is a "backward-scheduling" technique; that is, it starts with the end item due date and offsets subassembly and component requirements backwards from that date on the basis of planned lead times. When past-due requirements are recognized, the system attempts to reschedule according to the amount of time that can be squeezed out of normal lead time.

For manufactured items, a *compression factor* is applied to each component and subassembly, starting with the lowest level, until the required lead time reduction is achieved (if at all possible). Starting from the lowest level and going up the product structure is called "forward scheduling" (Figure 58B). The amount by which planned lead time can be shortened is discussed in detail in *Chapter 6, Manufacturing Activity Planning.*

For purchased items, the difference between the planning lead time and the emergency lead time is used for the same purpose, that is, determining how much lead time can be compressed.

If it is impossible to gain enough lead time even after applying the maximum allowable compression factor, the inventory administrator is notified that the respective end item due date should be changed.

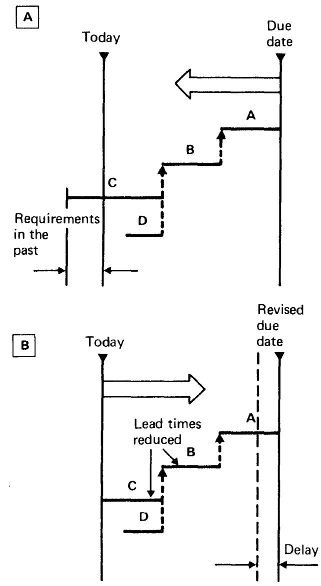


Figure 58. Planned order releases falling into the past are rescheduled on an expedited basis

The materials planning horizon must extend far enough into the future so that lower-level components can be effectively planned. Figure 59 illustrates the problem. The total manufacturing lead time for the product is 38 periods. If the planning horizon is only 35 periods long, requirements for item Z will be determined too late. Therefore, the forecast must be extended at least three periods to allow sufficient time to plan item Z.

effect of lead time offset on the planning horizon

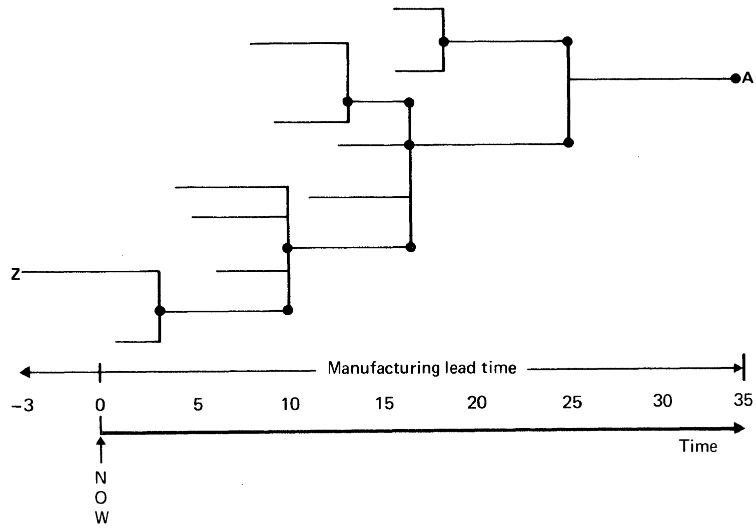


Figure 59. The materials planning horizon must extend far enough so that lower-level components can be started on schedule

It is for this reason that with multilevel product structures, the forecast must normally extend well beyond the longest manufacturing lead time.

The effect of lead time on each major product is analyzed, and the planning horizon set accordingly. The materials planning horizon can vary for each finished product or product family. In practice, however, this horizon is normally made uniform for all products, as it extends farther into the future than is required by the lead time aspect alone. The horizon should be sufficiently long to permit the existence of multiple planned orders per inventory item, for purposes of capacity requirements planning (see *Chapter 6, Manufacturing Activity Planning*).

specifying firm planned orders

A planned order represents no commitment as no action on it has yet been taken. Therefore, as the master production schedule is altered or other changes are processed by MATERIAL REQUIREMENTS PLANNING, alterations are constantly being made within the system to both the scheduled quantity and the due and release dates of the planned orders.

In some cases, however, it may be desirable to designate a planned order as "firm". This designation means that neither the due date, release date, nor quantity can be altered without the express approval of the inventory administrator.

Firm planned orders may result because of special arrangements with suppliers or because of the need to suit requirements outside the system, for example, reduction in the size of a planned order because of a pending engineering change. The inventory administrator can designate a firm order by using a terminal to place a code on the particular planned order record affected. He would also enter the firm quantity and date if different from the plan.

time-phased "order point" planning

Order point inventory control techniques are aimed at the placement of only *one* replenishment order at a time. These techniques were developed initially for inventories in the wholesale and retail trade, where the timing and quantity of only the *current order* are all-important.

In manufacturing, because the materials planning horizon must extend well into the future, multiple future replenishment orders are normally planned. Figure 60 shows an example of planned orders for an independent demand item being extended into the future (see also Figure 15 and the discussion of time-phasing "order point" items, under "Requirements for Independent Demand Items").

Period	1	2	3	4	5	6	7	8	9	10	11
Gross Requirements	9	9	10	10	10	10	11	11	11	11	12

[A]

On Hand	Safety Stock	Available On Hand
35	5	30

	1	2	3	4	5	6	7	8	9	10	11
Net Requirements				8	10	10	11	11	11	11	12
Planned Orders				40				50			
Order Release		40				50					

[B]

On Hand	Safety Stock	Available On Hand
30	5	25

	1	2	3	4	5	6	7	8	9	10	11
Net Requirements			3	10	10	10	11	11	11	11	12
Planned Orders			40				40				50
Order Release	40				40				50		

Figure 60. With time-phased order point planning, as with ordinary order point, a higher-than-forecast rate of customer demand results in an earlier order release date

With the traditional order point approach, if the demand rate increases, the order point is reached, and the order is released earlier than planned. Time-phased "order point" is shown in Figure 60, which indicates that the net effect, with multiple planned orders, is identical. In situation A the available quantity of 30 is allocated to cover the forecast demand in the next three periods. Therefore, planned orders are scheduled to be released in periods 2 and 6. In situation B, current demand has increased and available inventory has been reduced to 25. This causes an uncovered requirement in period 3. The system automatically advances the planned order release and due dates to cover the requirement.

Conversely, if demand fails to materialize, the original planned release date is now too early. The system therefore reestimates the new release date and reschedules all planned orders accordingly.

The requirements "explosion"

Gross requirements for an item that result from the *explosion* of a higher-level assembly are dependent demand requirements. The explosion process involves a planned order and the *bill of material* (product structure) for the item (Figure 61).

In batch net change processing, such requirements for a particular item are summarized and the basic steps of requirements planning are repeated for the next level. In continuous (or "real time") net change processing, each individual change in the gross requirements for the item is immediately processed; that is, requirements are netted and planned orders adjusted, as required. Thus a *partial explosion* is taking place continuously, as transactions are entered that affect the quantity or timing of planned orders.

For selected items (this can include all items) the system generates data during the explosion that allows requirements to be traced to their specific source, and inventory and orders to be associated with the specific requirements they are expected to cover. This is called "pegging" requirements, and is discussed under "Special Considerations in Inventory Planning and Control".

The explosion process starts with a change to the planned order schedule of an assembly. (A component is treated as an assembly if it has lower-level raw material, semifinished component, or dependent tool requirements.)

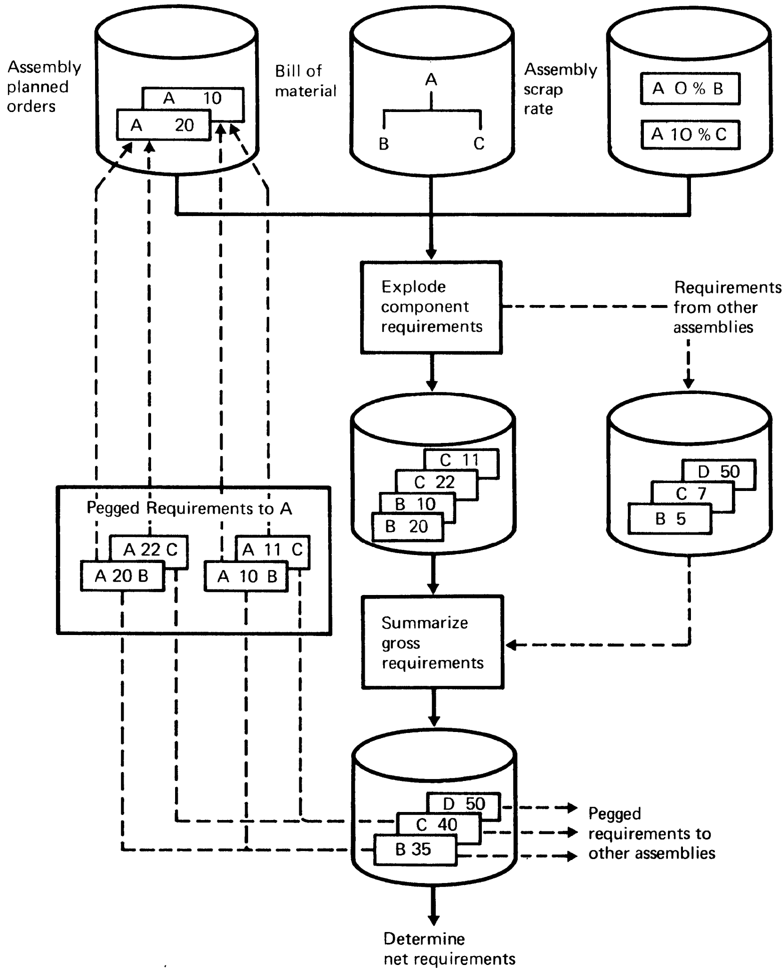


Figure 61. Basic functions of exploding component requirements

The example in Figure 62 shows an explosion for one subassembly. The net change to planned orders for assembly A is exploded by first retrieving the bill of material for assembly A from the data base created and maintained in ENGINEERING AND PRODUCTION DATA CONTROL. Only the single-level format of the bill is required; that is, only the components that go directly into A are considered. The bills for B and C will be retrieved only when *they* are exploded.

The next step is to multiply the planned order net change quantity by the usage (quantity per assembly) of each component in the bill. The results are added to (or subtracted from, as the case may be) the gross requirements schedules of the respective component items.

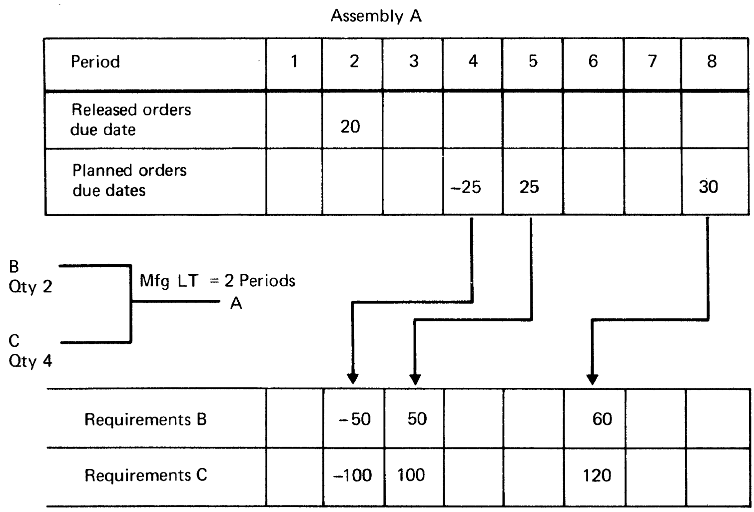


Figure 62. Explosion consists of multiplying the single-level bill of material by the net change to the planned orders

In the example, new requirements generated for B and C are dependent requirements of the planned order for assembly A. They are, in turn, processed (as discussed earlier under "Net Requirements", "Determining Order Size", and "Scheduling Order Release"), and the entire procedure is repeated until all levels have been exploded.

To reduce system time spent on inventory accounting and planning minor, low-cost dependent demand items such as rivets, screws, etc., these items are sometimes treated as independent demand items. Therefore, there is no need to determine their requirements via the explosion. A code in the structure record (bill of material) suspends the calculation for these items. This approach applies primarily to purchased items. Better results, particularly in the area of shop priorities, will be obtained if *manufactured* items are subject to the explosion process.

Special Considerations in Inventory Planning and Control

A number of special considerations are relevant to the subject of inventory planning and control. They are:

- Inventory classification
- Dependent demand/product structure relationship
- Engineering change effectivity control

- "Pegged" requirements
- Trial-fitting a proposed schedule change
- Projecting inventory investment
- Material requirements planning in a multiplant situation

A discussion of these subjects follows, in the sequence indicated.

Inventory classification

In some companies, every item in inventory is subject to the same degree of control. Experience has shown that this is not always the best policy, because the cost of tight control on low-cost items (nuts, screws, washers, etc.) can be greater than the cost of carrying a higher inventory to avoid shortage.

Inventory items may be classified into groups reflecting their relative importance. These classifications highlight areas of potential savings and increase control efficiency. The grouping can be done on a variety of bases. Classifying by annual usage value, normally called "ABC classification", is probably the best known method (Figure 63).

EVERETT MANUFACTURING CO.

ITEM NO.	ITEM COUNT	% OF TOTAL ITEM	ANNUAL UNITS USED	UNIT COST	VALUE	CUMULATIVE VALUE	% OF TOTAL VALUE
207061	1	.01	51,553	3.077	158,629	158,629	.48
216832	13	.12	243,224	.317	77,102	1,652,385	5.0
217036	43	.39	98,406	.470	46,251	3,304,769	10.0
059655	81	.74	6,768	4.876	33,001	4,957,154	15.0
203320	93	.85	4,250	7.369	31,318	5,254,583	15.9
108946	99	.9	44,560	.675	30,078	5,618,107	17.0
105322	110	1.0	8,680	3.286	28,522	5,882,489	17.8
112026	132	1.2	27,581	:930	25,650	6,609,538	20.0
516267	176	1.6	3,428	5.900	20,228	7,600,969	23.0
061981	209	1.9	52,765	.379	19,998	8,261,923	25.0
059282	308	2.8	1,105	14.676	16,217	9,914,307	30.0
188565	330	3.0	23,908	.640	15,301	10,443,070	31.6
216121	2198	20.0	7,239	.490	3,547	23,662,146	71.6
102018	2615	23.8	3,571	.840	3,000	25,050,149	75.8
549986	2747	25.0	14,774	.190	2,807	25,413,674	76.9
826621	3198	29.1	1,500	1.650	2,475	26,438,152	80.0
802374	3296	30.0	1,212	1.876	2,274	26,834,724	81.2
902613	9889	90.0	3,750	.048	180	32,915,499	99.6
162605	10,439	95.0	198	.505	100	32,998,118	99.85
546562	10,900	99.2	210	.143	30	33,034,471	99.96
506132	10,966	99.8	0	.062	0	33,047,690	100.0
613742	10,988	100.0	0	.073	0	33,047,690	100.0

Figure 63. An ABC classification

This method highlights the fact that a high percentage of the annual usage value (80%) is concentrated in relatively few items (20%) (Figure 64). The high-value items can further be classified as shown (A and B items). The percentages will vary slightly in different kinds of companies.

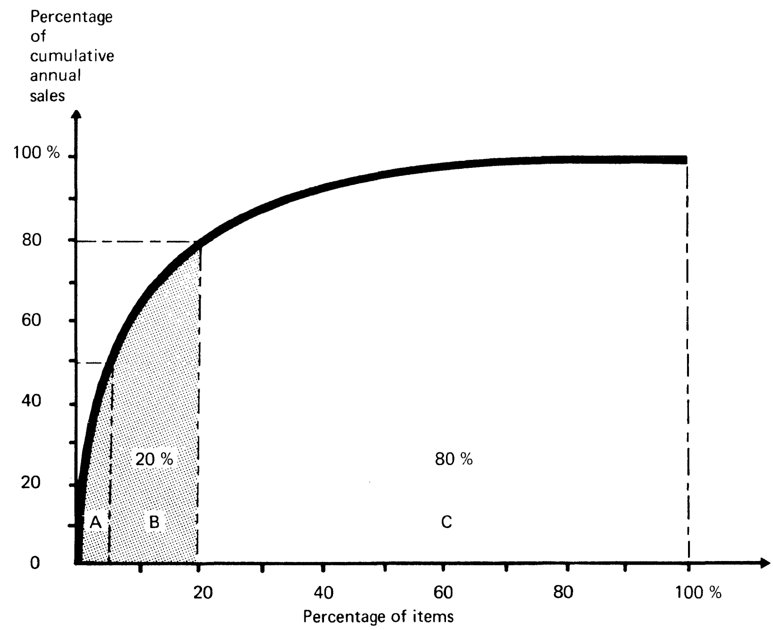


Figure 64. The distribution by value is made by extending annual usage by unit cost

The 80/20 relationship (or a percentage very close to it) holds true in many other areas. For example:

- 80% of rush order requests come from 20% of the customers.
- 80% of late purchase order receipts are caused by 20% of the suppliers.

In classifying inventory, the following factors must be considered:

Number of classes. Inventory can be classified into any number of groups, not just A, B, and C. Each company must decide on the number and types of categories it can effectively use.

Boundaries of the classes. Setting the boundaries when classifying the inventory is mainly a matter of judgment. Since the main result of the classification is to determine a basis for applying different control policies, the boundaries should be set to balance the total effort required for planning and control against the cost of carrying excess inventory.

Placing tight control on high-usage/high-cost items will keep inventory investment low. But inventory may be classified on other bases than unit cost. Other bases include:

- Profit contribution (shipments times profit per item). Control is concentrated on high-profit items.
- Marketing policy (sales by customer or customer type times profit or sales value). Control is concentrated on those markets to which management wishes to give the better service.

A weighted combination of these and other classifications is possible. For example, both annual usage cost and profit can be considered.

Under INVENTORY MANAGEMENT, the utilization of inventory classification is not so much within the process of material requirements planning (which applies the same precision and frequency of planning to every item) as in areas of policy, and physical control. For example, different treatment of A, B, or C items can be applied in the following areas:

Purchased item safety lead time

Frequency of cycle counting

Lot sizing

Physical storage

Size of issues to an assembly line

Safety stock

Scrap allowance for manufactured items

Control of overshipments, and premature deliveries, by suppliers

Relationship of dependent demand to product structure

The relationship between a dependent demand component and the product in which it is used is defined in a bill of material. The creation and maintenance of this data, also called "product structure" data, is discussed in *Chapter 1, Engineering and Production Data Control.* The structure is sometimes referred to as a level-by-level bill of material. The product structure can be used to relate item dependencies such as:

- *Semifinished components and assemblies.* These should be treated as subassemblies dependent on the finished item to which they will be converted. For example, a rough casting that can be made into any of five finished castings is dependent on the schedules of the five items. In this case, the finished castings should, in effect, be treated as assemblies and the rough casting as a common component. Subassemblies that cannot be completed until specific customer requirements are known (plating, painting, etc.) should also be treated this way (Figure 65).

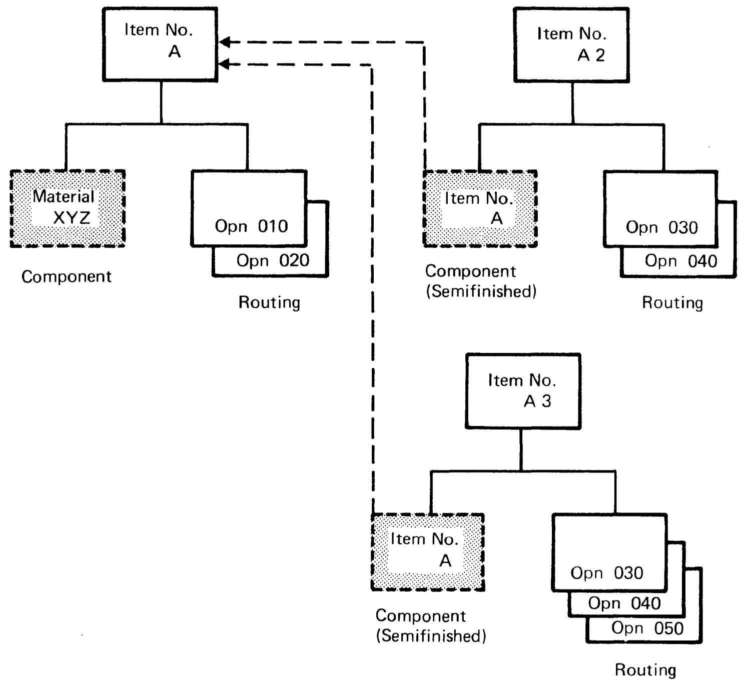


Figure 65. Semifinished components and assemblies are treated as another level of the bill of material

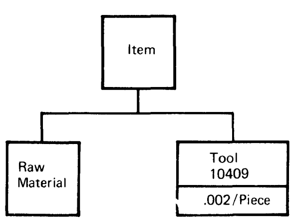


Figure 66. Tool requirements as part of a product structure

- *Items with identical initial operations.* Items on which the initial series of operations is identical, and which are then split into several different shop orders, can be treated in the same manner as semifinished components. A part number is assigned to the item as it is at the end of the identical operations. It becomes a dependent demand component of the different fabricated items into which it is made (Figure 65).
- *Consumable tools.* Requirements for consumable tools, especially if significant, can be part of a product structure (Figure 66). They are stated as the amount of tool consumed per item. The same treatment could be applied to dies subject to grinding, etc.

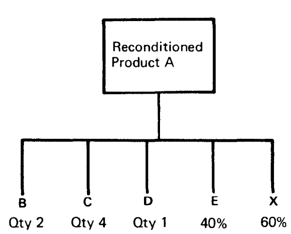


Figure 67. In reconditioning, component usage may be stated as a percentage of the normal requirements

- *Variable part usage per assembly.* In some cases, exact usage of a component in an assembly is difficult to determine. For example, when equipment is being reconditioned, part requirements are not known until the product is dismantled and the condition of the parts examined. The items that are always replaced are treated as a product bill of material. The variable parts are treated as product options, that is, with a forecast percentage of normal replacement (Figure 67).

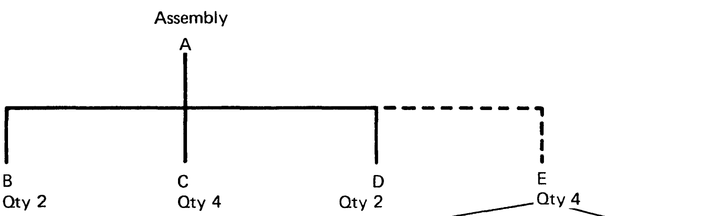
Further uses of the product structure are discussed in *Chapter 1, Engineering and Production Data Control.*

Engineering change effectivity control

The proper timing of engineering changes is essential to MATERIAL REQUIREMENTS PLANNING. The types of engineering change affecting it are those causing additions, deletions, and/or changes in quantity to product structures (bills of material). Changes affecting manufacturing routings, such as those that change the method of manufacture, are not of concern in INVENTORY MANAGEMENT except for their effect on manufacturing lead time.

structuring engineering changes

A detailed discussion of how changes are entered into the system is presented in *Chapter 1, Engineering and Production Data Control.* Figure 68 summarizes how a change is structured.



Part No.	Qty per Assembly	Eng. Chg. No.	Action
E	4	4063	Add

Eng. Chg. No.	Effectivity Basis	From	To
4063	Date	505	

Figure 68. The structure of a pending engineering change as it would appear in the system data base

In this example, two of component D are being replaced by four of component E. Part E is added to the product structure of assembly A. The structure records for both D and E are associated with a controlling engineering change number and record. This record indicates the effectivity basis for the change. (For a more detailed description of these records see *System Data Base.*) In the example, the change is to be effective on shop calendar day 505. A temporary change would utilize the "to" field to show when the change no longer applies, or when it will be superseded by another change.

basis for effectivity

There are four basic ways to specify the effectivity of an engineering change:

- Immediate
- Change on a particular day (effective date)

- Change at a specific quantity (typically: use up) of available inventory
- Change at a specific serially numbered finished product or lot of components

change based on date

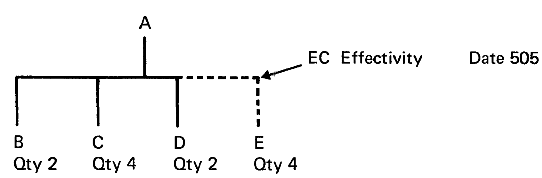
If the engineering change is effective immediately, the affected inventory item records must be altered promptly to reflect this change. Different procedures to accomplish this may be used, ranging from manual intervention to alter the inventory records, to fully automated methods.

Implementing a change effective on a specified date is done during the explosion of requirements using the product structure record. If the structure records for the assembly indicate a pending change, the system automatically switches from one structure to the other for the period indicated. This changeover is based on the action codes (add, delete, or change) in the specific structure record affected (Figure 69).

change based on quantity

The item record (for both parts affected) should be coded to indicate that a product structure change is pending within the materials planning horizon. This causes the lot-sizing rules to be altered to take into account a possible discontinuance of the part.

The effectivity of the change may be specified either at a quantity of zero (change at "use up") or at a quantity representing how much is to be reserved for usage as service parts, etc. The system checks the existing availability (on-hand plus released orders) and, on the basis of known requirements, estimates what date the change will be effected. This date is then placed in the engineering change record.



Period Start Dates	485	490	495	500	505	510	515	520	525	530	535
Net Requirements A LT = 5 Days		5	10	20	30	10		10	40		
Dependent Reqmt. D	10	20	40								
Dependent Reqmt. E				120	40		40	160			

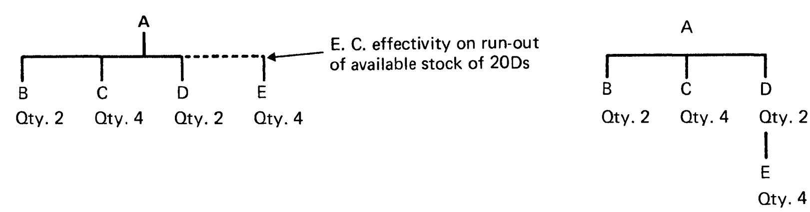
Figure 69. When exploding requirements, the system switches the structure of items exploded on the basis of the effectivity date

Figure 70 illustrates how the due date is determined for the new item. The new item (E) is held as a *component* of the item being replaced (D). The estimated runout date for D is calculated on the basis of known requirements. As this date approaches, an order would be placed to replenish D and also any component parts needed to make it. As there are no orders to cover requirements for E as yet, an order to manufacture E is generated to be available in the correct quantity and at the time that D runs out. The order for D and for any of D's components not now required is automatically suppressed.

Any change in the requirements for D is automatically reflected in a change in the due date for E. The system alters the effectivity date. Because the exact date cannot be accurately known, the system can be instructed to allow a special safety lead time on the first planned order of the new item. The change is implemented in the same way as if the change were based on a date.

change based on serial number

When "pegging" is utilized (see "Pegged Requirements"), the pegged requirement for the lower-level item can be traced to the order number of the product that generated it. Therefore, it is possible to associate a detailed requirement with the serially numbered product on which it will be used.



Requirements

Period	485	490	495	500	505	510	515	520	525	530
Net Requirements A		5	10	20	30	10		10	40	
Dependent D	10	10								
Dependent E		20	80	120	40		40	160		

E is specified as a "component" of D

Figure 70. The system determines when current stock of the old item will run out and incorporates the new item at that point

The effectivity date and serial number are held in an engineering change record linked to the product structure record, the date being calculated during the explosion.

Lot sizes may have to be modified to meet the requirements of incorporating the change at a particular serial number. This is done by calculating the number of items required, plus any allowance for scrap, from the start of the particular lot to the serial number on which the modification is to be incorporated. The explosion process is the same as for changes based on date.

Incorporating a change starting with a particular lot of items is similar to the above, except that the lot number is used, instead of the serial number, to control the change.

implementation of engineering changes

In determining the date on which the engineering change is to be incorporated, the system uses available data such as effectivity date, stock runout point, or planned incorporation on a particular product. As the effectivity date approaches, the engineering change coordinator (or inventory administrator) must ensure that the change is effected as planned. The actual implementation of the change should be fed back to the system in order to maintain effective engineering change history data. This information would include the actual serial number and/or the date on which the change was made.

Pegged requirements

MATERIAL REQUIREMENTS PLANNING plans requirements and orders for individual items in a process (explosion) that proceeds from the top (end items) to the bottom (purchased components and raw materials) of the product structure. In the standard process, requirements for each item are summarized, usually by time period, which obscures the detailed requirement quantities individually derived from the various "parent" items. Furthermore, the standard requirements planning procedure does not provide a connecting link *upwards* to parent item records. Consequently, a display or printout of any item record shows requirement figures that are valid but *anonymous.* This limits the uses of the standard system.

"Pegging" individual requirements to their specific sources is a significant feature of MATERIAL REQUIREMENTS PLANNING that provides an *upward traceability* from component to parent item record, all the way up to the end item requirement stated in the master production schedule.

Pegged requirements are used, for example, to:

- Check the source of requirements.
- Trace the effect of component delays on the delivery date of the finished product. For example, if a lot of castings is scrapped, which customer orders will be affected and what will be the extent of the delay?
- Examine the validity and significance of a system-generated request to change the due date of an order.
- Discover the effect of a pending engineering change on a customer's order, or trace upwards to the product serial number on which the change will become effective.
- Maintain the customer's identity down through orders for lower-level components, for purposes of lot costing, inspection standards, etc.
- Resolve contention between individual requirements for existing inventory and open orders.
- Determine to which of several stocking locations a receipt should be sent.

methods of pegging requirements

When pegging is applied, two additional steps are added to the logic of MATERIAL REQUIREMENTS PLANNING. One is to retain the requirements detail, in addition to summarizing requirements. This will establish effective upward traceability.

Figure 71 illustrates the concept of pegging and the basic data required. When planned orders for assemblies A and B are exploded, they generate individual (detail) requirements. If an item (E) is designated as *pegged*, its requirement is not merely summarized with other requirements; in addition, a detailed record is retained. The number of the planned order generating the requirement is associated with this data.

The second step is to allocate the existing and planned inventory to the detail requirements, and record this allocation.

To do this, additional connection fields (segments) are created and maintained. These consist of the order number to which the order or on-hand quantity is being pegged, along with the allocated quantity. In the example in Figure 71, the released order 28040 is pegged to three different detail requirements records; planned order 28777 is pegged to two requirements, leaving a quantity of 80 to cover future requirements.

In Figure 71 the additional data needed for the pegging of inventory and orders is indicated by the shaded areas (the assumption here is that requirements are already being held in date/quantity format). All of the data needed for pegging is generated at the time component requirements are exploded.

Pegging can also be used to allocate available inventory and planned orders for finished products to customer orders. In a sense, the customer order becomes the top-level requirement.

The procedure just outlined is called "single-level pegging" because it identifies only the next higher level to which the item is allocated. Further tracing upward to the end item shop order uses the system-generated connection segments.

As an option, end item shop order identity can be carried down to each component order. This can be achieved by maintaining a record for every intermediate assembly order using the components, or, to conserve file space, by maintaining only the end item identity and the next where-used shop order. This option is called "full pegging". (For further details on pegging see the example "Order Dependence" in *System Data Base.*)

The choice between single-level and full pegging depends on computer economics. The same information can be retrieved either way. The where-used type of retrieval used for single-level pegging reduces file space but increases computer time during the retrieval. The converse is true for full pegging.

items subject to pegging

A code in the item record designates whether an item is to be pegged. Pegging is usually performed only for items critical to the assembly processes, but can apply to any or all items. Even if requirements are exploded for minor items like screws, rivets, etc., they are usually not pegged.

If an item is designated as pegged, all requirements for the item, including any independent demand forecast, would be pegged to the available inventory or orders covering them.

uses of pegged requirements

The system can use pegged requirements for many different purposes, as previously listed. The following is a discussion of some of these uses.

Tracing Effect of Component Delay. Either single-level or full pegging allows the effect of a lower-level component delay to be traced to the customer orders or end item schedule it affects. If delays are encountered, the system, using its pegging facilities, can reschedule the other related component orders accordingly, and capacity is not wasted trying to produce other components affected by the delay.

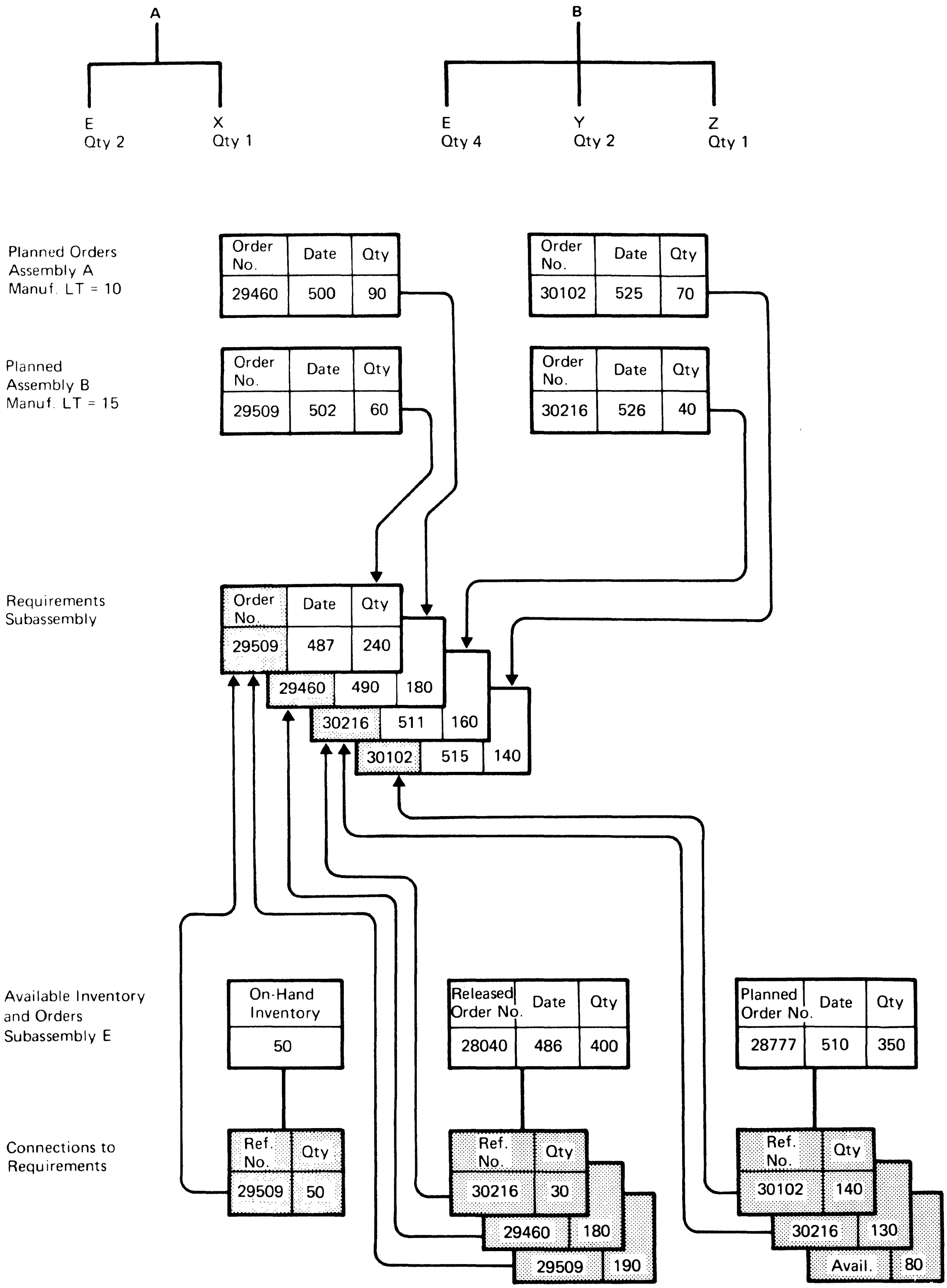


Figure 71. Pegging is the connection of detail requirements to their specific sources

Figure 72 portrays this situation. Subassembly B is delayed; this forces the delay of A. The shop order for subassembly D is also covering a requirement for assembly X and therefore cannot be delayed. However, the shop order for C is assigned exclusively to A, so its planned order due date can be revised to a later date. Its priority is lowered and other, higher-priority shop orders contending for the same work center are given preference. If there are no other higher-priority orders, C is finished on schedule.

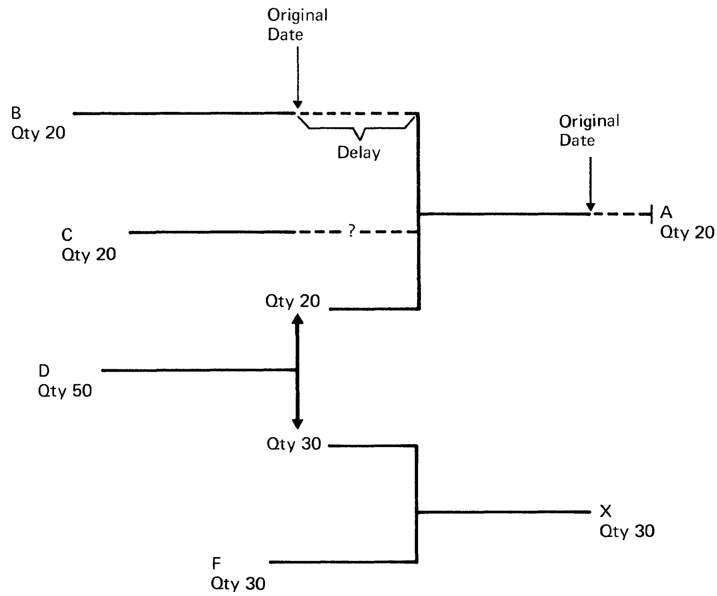


Figure 72. Pegging allows the priority of released orders to be revised on the basis of delays in associated orders

Details on how the system uses pegging to associate component requirement networks are given in *Chapter 6, Manufacturing Activity Planning.*

Checking the Validity and Significance of a Reschedule Message. MATERIAL REQUIREMENTS PLANNING has the ability to reevaluate, continuously, the validity of originally established due dates for released orders. In those cases where the date of actual need has changed and differs from the scheduled due date, the system generates a message to the inventory administrator, recommending that the order be rescheduled. Under another option, the system reschedules the order automatically.

In the former case, the inventory administrator can use the pegged requirements capability of the system to verify the validity, and significance, of the message. He may choose not to follow the system's recommendation.

For example, in the case of a request to advance a component order due date, he may trace the requirement to an end product, learn that demand is running below forecast, and ignore the message.

Segregating Particular Product Orders. Some companies, especially those producing to government contracts or making very large finished products like turbines, must sometimes put restrictions on the requirements that can be grouped together into a planned order. The restrictions are usually imposed by the customer for certain products. Reasons for the restriction may include:

- A special lot-costing method, as with certain government contracts
- The application of special inspection standards to particular orders – for example, military (or commercial) standards
- The need to provide management with the capability to expedite or delay items peculiar to a specific customer order

How the orders are grouped together (lot-sized) depends upon the combination of either the *order control code* or *item control code* and the order number associated with each pegged requirement. The effect of the two codes is shown in Figure 73.

The *item control code,* carried in the item record, is used to selectively identify items that should be ordered only in lot sizes related individually to each separate order number. If this code is present, separate lot sizes of the item are determined for each order (see Figure 73B). For items not containing the item control code, all requirements can be lot-sized normally (Figure 73A).

The *order control code* is used to lot-size only items within an order, whether they have an item control code or not. The code is carried in the order record. By this means, special control procedures for all items in an order can be instituted – for example, where particular inspection standards have to be applied (Figure 73C).

Resolving Contentions for Components. Pegging existing and planned inventory to a requirement can be considered as an advance allocation or reservation. The allocation is made on the basis of the date of the requirement; that is, the earliest requirements date is covered first. If requirements are generated for the same day, the priority assigned to the order decides the sequence of allocation. Problems arise with critical components in limited supply, or with items that are short.

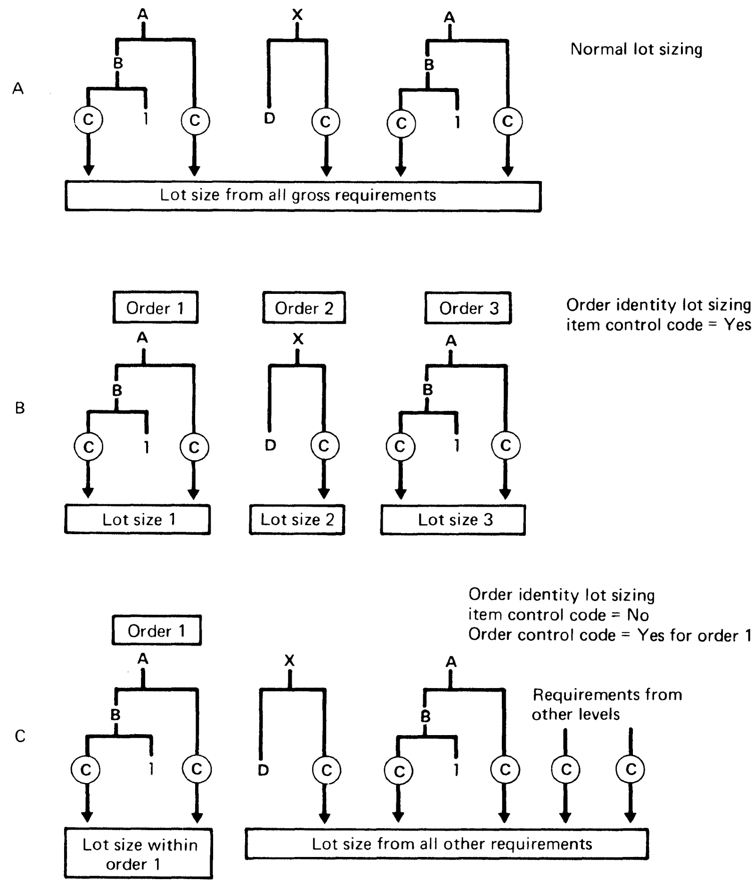


Figure 73. If desired, pegging allows the grouping of requirements for lot-sizing purposes to be restricted to particular customer orders or to particular items and orders

If requirements are not pegged, but are grouped together, contentions for available components can only be resolved at time of assembly order release. Upon completion (receipt) of any component order, the requirements to which it is pegged can be reexamined. Allocations previously made can sometimes be restructured to result in a better solution (see Figure 74).

Determining Storage Location for Receipts. When multiple locations are maintained for the same item, a problem at the time of receipt is to decide how to allocate the quantity to the various locations. Allocation should be based on where this particular receipt will be used.

With pegging, each order, and therefore each receipt, is associated with the specific requirement (that is, higher-level planned order) it is covering (Figure 75). The requirement, in turn, is associated with the higher-level item's manufacturing routing. The routing specifies the operation number and work center at which the material is used. The

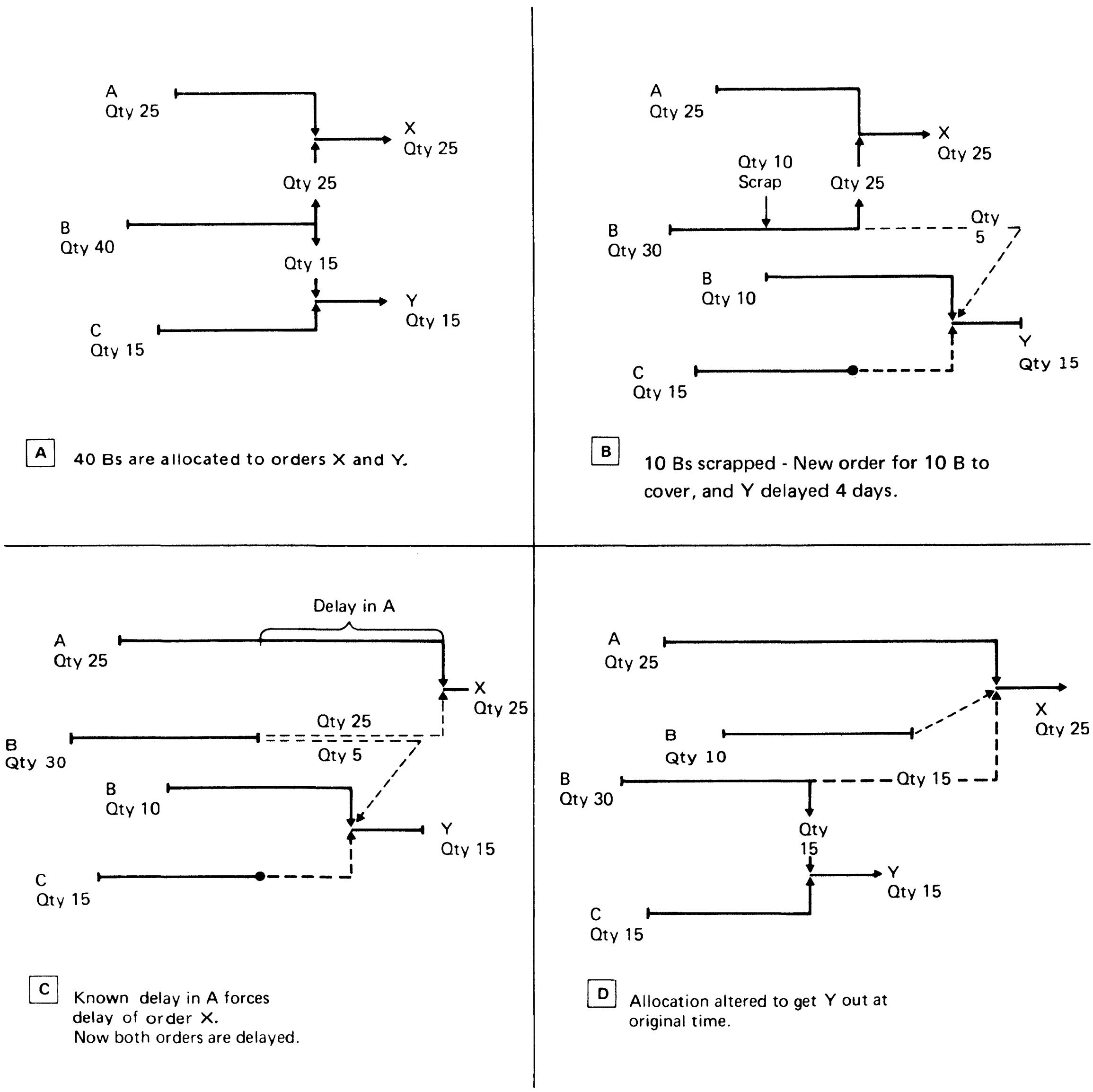


Figure 74. When multiple delays are encountered, the system reevaluates its pegging records in an attempt to optimize the allocation

work center record is coded to indicate which storage location (warehouse) normally supplies parts. At time of receipt the pegging function initiates a trace to the proper storage locations and the receipt is split and routed accordingly.

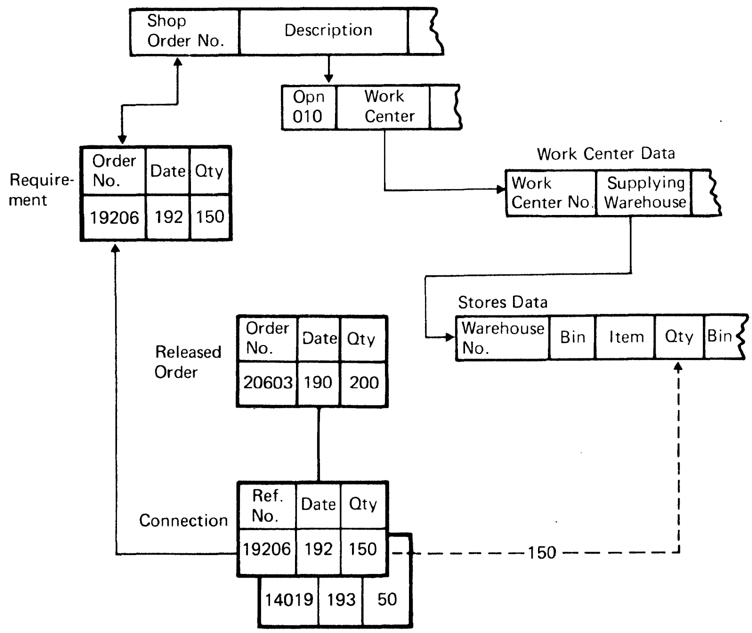


Figure 75. Pegging allows a receipt to be routed to the closest storage location supplying the work center

Trial-fitting a proposed schedule change

The *net change* capability of the system allows the detailed effect of any one potential change in the master production schedule to be determined in advance.

The net change to the schedule is entered with a special code indicating a trial fit. This ensures that no records are affected. During the explosion procedure, as an item record is retrieved, it is copied and stored in a temporary file. Changes are made to this temporary record.

The procedure followed is identical to that used by MATERIAL REQUIREMENTS PLANNING, except that the copied records are used. When all levels have been processed, the records on the temporary file are compared with the original records. The changes are calculated and summarized for the manager proposing the change. One example of how the change can be summarized is shown in Figure 76. The probable effect on overtime, the utilization of capacity, and the amount of lead time compression required are derived by feeding the net changes to orders to CAPACITY REQUIREMENTS PLANNING, which also processes these alterations on a net change basis.

Type Order Affected	Status	Order No.	Part No.	Planned Delivery Date	Required Delivery Date	Required Improvement in Days	Ratio-Improvement to Days Remaining	Customer or Vendor No.
Purchase	Rel.	11021	165409	350	340	10	.33	76124
Purchase	Rel.	11011	180536	347	340	7	.25	10665
Purchase	Plan		050247	351	344	7	.15	21199
Shop	Rel.	56193	160514	352	340	12	.40	
Shop	Plan		290611	352	344	8	.35	
Shop	Plan		260340	357	348	9	.20	
Customer		89973		364	361	3		64226

Load Summary ECU = Excess Capacity Utilized AOT = Additional Overtime

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Machining	ECU				40		20	20		10						
	AOT		60	55	20		60		20	10	10					
Assembly	ECU					20	20	10	5							
	AOT				40											
Total	ECU				40	20	40	30	5	10						
	AOT		60	55	60		60		20	10	10					

Figure 76. Net change capability can be used to determine the detailed effect on the material plan. This is an example of a report summarizing the effect

The type of report shown in Figure 76 can serve as a basis for accepting or rejecting the proposed schedule change. If the result is infeasible or considered too expensive, alternate schedule dates can be tried. Procedures to reverse the trial entries are not necessary since the actual records are not altered. Real-time processing and inquiry can proceed normally.

Projecting inventory investment

The system knows the planned inventory availability of each item through its materials planning horizon. This serves as an accurate basis for estimating the level of future inventory by time period. This data can be used to plan cash requirements, to evaluate trends in inventory investment, to institute changes in inventory policy, etc.

Because of the effect of offsetting for lead time, the requirements for lowest-level component items, and therefore their planned availability, will not be indicated over the entire planning horizon (Figure 77). Therefore, if it is desired to estimate inventory investment beyond the relatively short planning spans of the low-level items, the system can estimate future availability by making a forecast based on the current plan.

A typical inventory projection is shown in Figure 78.

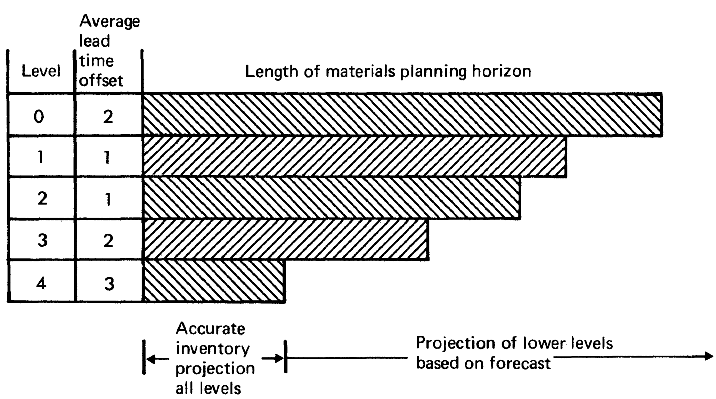


Figure 77. Inventory level projections can be made on the basis of the span of requirements within the materials planning horizon

INVENTORY INVESTMENT FOR PLANNING HORIZON STARTING 04/10 — TODAYS DATE 497

CURRENT INVENTORY LEVEL TOTAL ON—HAND VALUE = 1,939,500 INCL. 24,190 SAFETY STOCKS AND 53,650 ALLOCATED

PLAN FOR NEXT 10 PERIODS OF 5 WORKING DAYS

PERIOD START DATE	FORECAST VALUE OF SALES (AT COST)	PLANNED CLOSING STOCK VALUE (NOT INCL W.I.P.) FOR PERIOD	NET CHANGE	- - -VALUE OF- - - RELEASED PURCHASE ORDERS	PLANNED PURCHASE ORDERS	RELEASED MANUF'G ORDERS	PLANNED MANUF'G ORDERS - - -BY DUE DATE- - -	MATERIAL & COMPONENT ISSUES TO W.I.P. FOR JOBS STARTING
500	5,314,500	2,965,600	1,026,100	1,971,100	0	4,834,900	525,400	998,600
505	2,402,400	2,675,300	290,300-	1,872,000	40,400	1,910,300	3,475,700	1,359,100
510	2,044,600	2,658,900	16,400-	1,510,900	309,000	1,440,900	3,632,100	237,300
515	2,594,400	2,466,500	192,400-	1,024,000	886,100	619,800	4,246,600	695,200
520	802,000	2,125,500	342,000-	420,000	1,548,800	414,600	4,454,200	956,600

TOTAL NUMBER OF ITEMS SCHEDULED = 45,500 AVERAGE INVENTORY OVER PLANNING HORIZON = 2,538,360

NO. OF PLANNED PURCHASE ORDERS = 8,070

NO. OF PLANNED MANUFACTURING ORDERS = 3,190

Figure 78. An inventory investment projection can serve as a basis for planning cash requirements

Material Requirements Planning in a multiplant situation

Figure 79 shows a situation where several interrelated plants are producing parts for a product. Product A assembled in plant 1 generates requirements for plant 2 and so on through five levels. Assuming weekly batch requirements planning at each plant, the impact on component E, caused by a schedule change to assembly A, will not be known for five weeks. This means that large inventories must be maintained to absorb fluctuations in interplant demand. It probably also means the company reacts very sluggishly to customer requirements.

decentralized planning

The net change capability of MATERIAL REQUIREMENTS PLANNING, together with high-speed data transmission links between the plants, can significantly reduce inventory and improve reaction to customer, including interplant, demand. If each plant transmits interplant orders on a 24-hour cycle, the requirements for component E will be known in five days.

As indicated in "Determining Order Size", lot sizing should be done at the producing plant and changes to the planned order shipment dates sent via data transmission lines back to the receiving plant.

centralized planning

The example just described assumes that planning for each individual plant's requirements is done separately, with a local computer system. The alternative to this approach is a central computer facility, and a common MATERIAL REQUIREMENTS PLANNING system. In this situation the demand changes for all plants can be processed at the same time and there is no processing delay.

All items affected by the change, from all plants, are completely processed before any interplant orders are generated. This mode of operation requires central control over plant inventory records, or direct access to these records.

Processing changes in the master production schedule in this manner provides an efficient means of implementing demand changes involving several interrelated plants; elapsed time is minimized. The disadvantage is that central records (or access to them) must be maintained for remote plants; this increases data transmission cost and complicates control procedures.

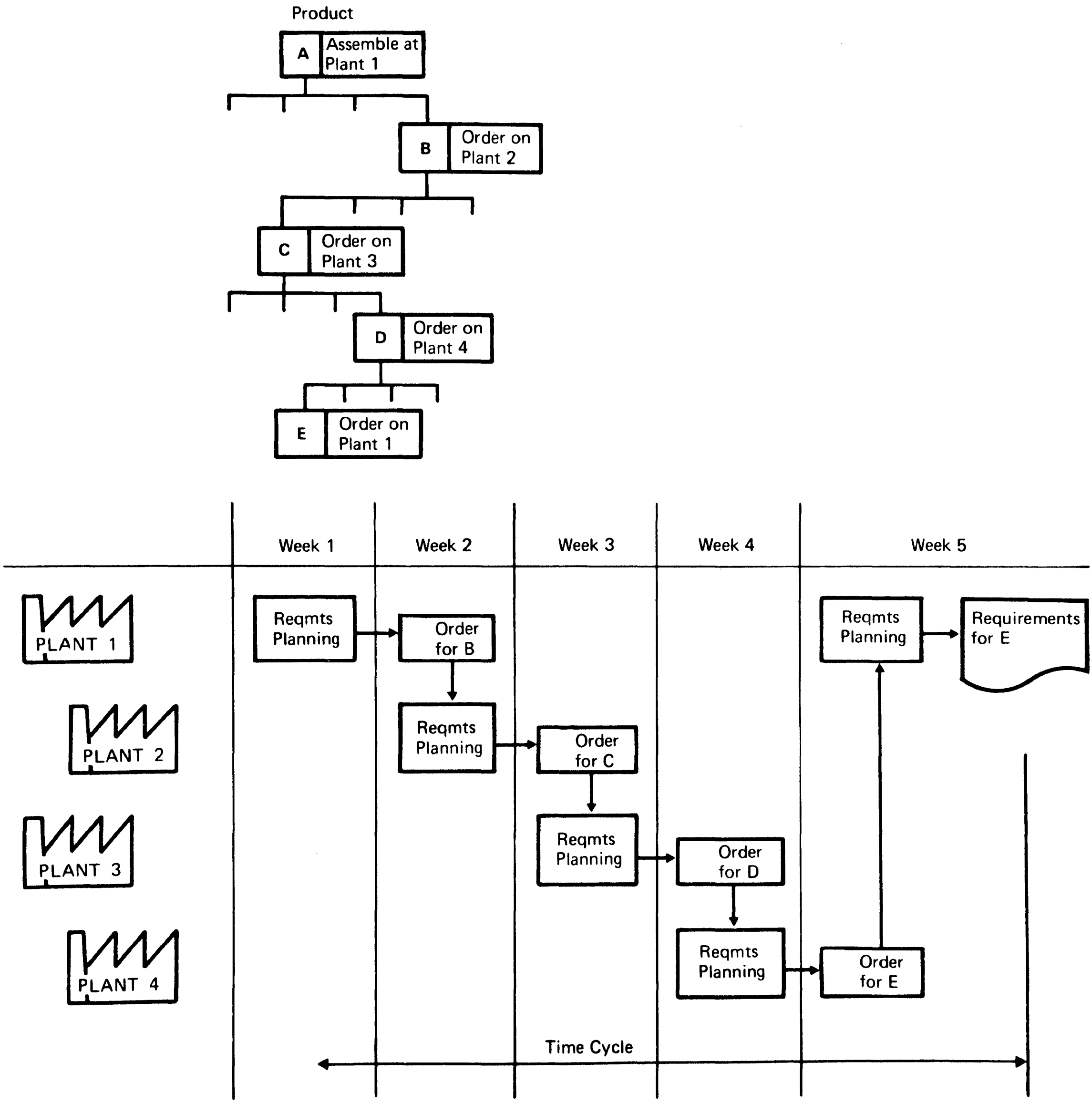


Figure 79. With batch-oriented MATERIAL REQUIREMENTS PLANNING, the planning cycle of companies with interrelated plants can be long

Field Warehouse Inventory Control

When a company-controlled distribution network of branch warehouses is interposed between the manufacturing plant and customer demand (Figure 81), inventory planning procedures must be somewhat modified.

The plant's production schedule is not based directly on customer demand, but on the replenishment schedule of each branch warehouse. In most situations, there is a significant difference between the timing of customer and warehouse demand; unless this timing difference is recognized, it will result in shortages or excess safety stocks at the warehouse level.

The reason for this difference in the timing of demand stems from the following:

- The warehouse may perform some kind of packaging, labeling, or even assembly function, and this is done in lot sizes that may cover several periods' demand (Figure 80). The plant demand will therefore be discontinuous.
- Requirements may be grouped into lot sizes to reflect handling cost at the branch warehouse. For example, minor items like washers, gaskets, etc., may be shipped only once every few months. This also causes discontinuous demand on the plant.
- Planned replenishment orders for a warehouse or group of warehouses may be combined to take advantage of reduced shipping costs by filling a truck or railroad car.

Period	1	2	3	4	5	6	7	8	9
Net forecast customer demand	0	20	20	20	20	20	20	20	20
Packaging schedule		80				80			
Demand on plant	80				80				

Figure 80. A packaging step performed at the warehouse will alter the demand pattern

Determining warehouse requirements

To determine customer demand on warehouses, a demand forecast must be developed for each item stocked by each of the warehouses. Judgment modifications, as outlined in *Chapter 3, Forecasting,* can be applied to reflect local conditions.

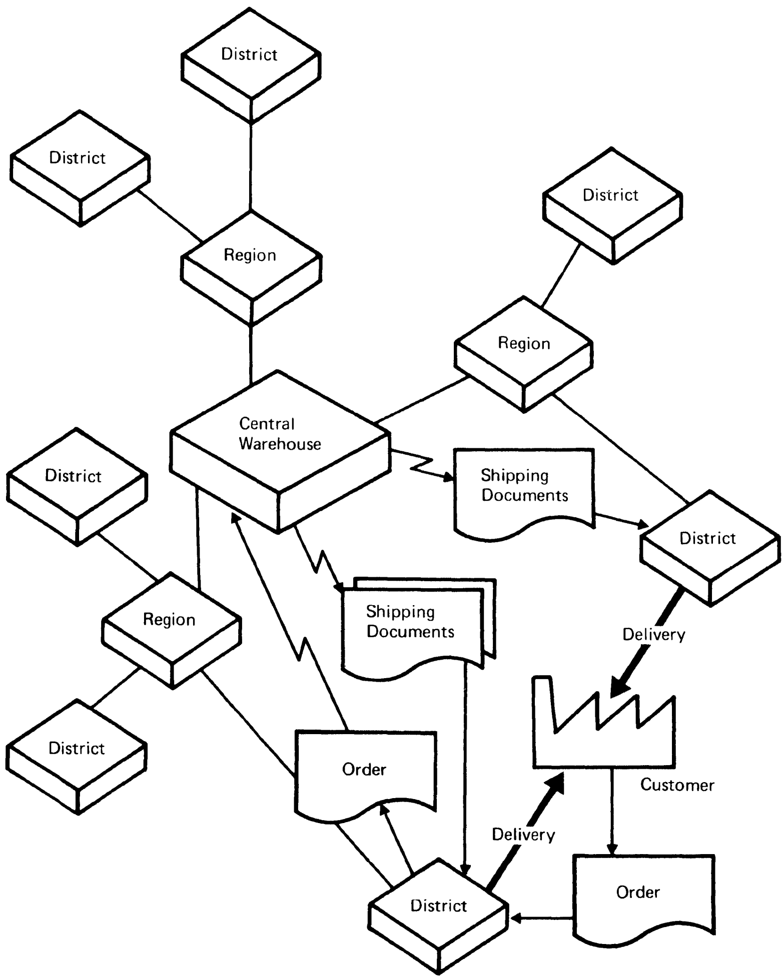


Figure 81. A company-controlled distribution network between the customer and the plant requires system modifications

The procedure for developing the requirements schedule (based on forecast) can be identical to that outlined for independent demand requirements in *Chapter 4, Master Production Schedule Planning.*

Once requirements have been forecast, safety stock and net requirements are established as discussed under "Material Requirements Planning". The safety stock calculation is based on the forecast error at the warehouse level. This means that the total safety stock maintained for all warehouses combined is higher when a field or branch warehouse distribution network is present (Figure 82). However, if there is relative freedom to cover customer requirements out of any one of several warehouses, safety stock can be calculated on a national level and allocated to the branches on the basis of their sales volume.

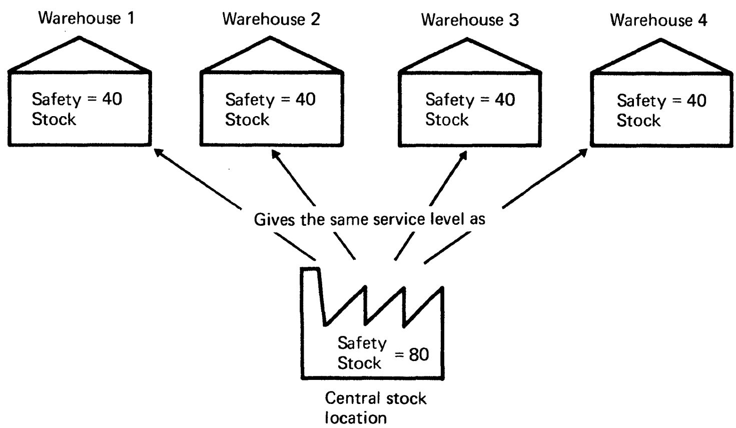


Figure 82. With a branch warehouse distribution network, safety stock must be larger

As indicated previously, safety stock is subtracted from the warehouse's inventory (on hand plus on order) to determine net requirements.

Determining order size and shipping schedule

For field warehouses, the major difference in the approach to inventory planning lies in the area of determining replenishment order size (lot sizing).

An *economical handling quantity* should be established. It is calculated as indicated under "Determining Order Size". However, the order cost elements are different. Only the incremental costs of picking, packing, unpacking, and storage should be considered.

For purposes of determining an economical handling quantity, shipping costs per item are considered independent of order size and are therefore not included in the calculation. In reality, however, shipping costs usually vary with the volume shipped. After lot sizing for handling purposes, the system groups the orders so that the minimum or truckload size is attained. This has the effect of altering the release dates and due dates of the planned replenishment orders (Figure 83).

Planned Order Schedule

Period	1	2	3	4	5	6	7	8	9	
Item A			30				30			
Item B		10			10			10		
Item C	5		5		5		5		5	
Shipping Schedule	*				*			*		
Coverage with equal truckloads	└──	────	───→		└──	────	───→	└──	────	──

Revised Planned Order Schedule

Item A	30				30			20		
Item B	10				10			20		
Item C	10				10			10		

Figure 83. Grouping orders to obtain full loads can significantly affect the demand pattern on the plant

If warehouses are replenished on a fixed schedule, say once a month or once a week, the combined planned orders will almost never exactly equal a truckload or multiple truckload quantity. The system trims or increases the shipping quantity by slightly adjusting planned order sizes or, if larger modifications are required, by moving planned orders from one period of planned shipment to another. The lead times, and therefore the safety stock calculations, must take into account the possible delay of shipment because of this grouping.

The planned order schedule thus revised now becomes the primary demand input to the plant's master production schedule. In this case, plant requirements are not forecast. As indicated, they are *dependent* upon the forecast and shipping schedule for each of the warehouses.

Allocating a fixed production schedule

The procedure just described is sometimes called a "pull" type system; that is, customer demand is causing products to be "pulled" from the plant towards the customer, according to the level of demand.

When a company produces finished goods inventory as a result of, say, stabilizing the production level, the excess inventory may be allocated to the branches on the basis of their forecast demand. This prevents storage problems at the plant and, by placing the product at the locations from which it will be shipped to the customer, may allow sudden surges in demand to be met. This is called a "push" type situation.

The quantity produced at the plant is allocated, or "pushed", to the branches in proportion to their demand rates and service objectives. The system summarizes demand on each warehouse until the quantity to be placed into the field has been achieved. This is shown in Figure 84.

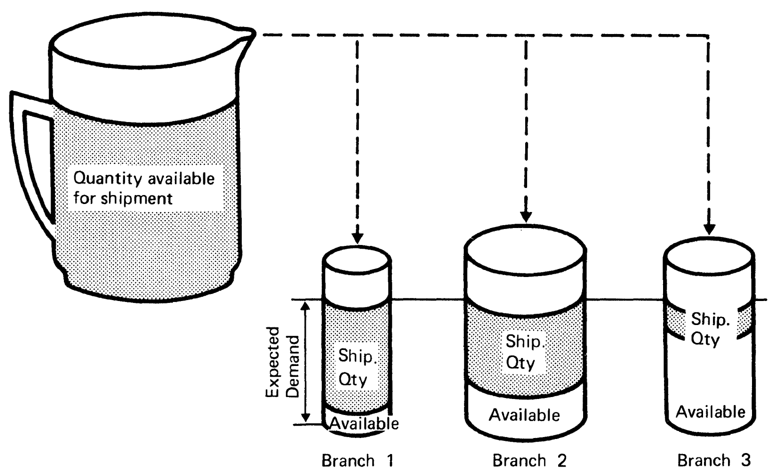


Figure 84. When excess quantities are produced at the plant level, they can be allocated to branches on the basis of expected demand

Organizing for fast response

Unless the branch is large enough to support its own inventory planning system, forecasting, requirements planning, calculating safety stock, lot sizing, etc., are usually performed for all warehouses at one central location. Therefore, unless demand transactions are entered into the system quickly, it reacts very sluggishly to changes in demand. High safety stocks have to be carried to absorb fluctuations during the processing delay. Transaction error correction is complicated because events occurring days or weeks ago are difficult to recall accurately.

To alleviate these and other problems, terminals can be placed in the warehouses. They can be used to enter the order and notice of shipment, and transmit the data to the central processing location (Figure 85). The central location uses the order information to update warehouse inventory files. The system can also prepare the shipping papers and transmit them back to the branch warehouse.

The branch terminals can also be used to inquire into the inventory status and planning information stored centrally. If the branch warehouse managers are responsible for the inventory level and the level of stockouts, the terminal can also be used to alter the branch's inventory level control factors, such as an item's service level percentage or lot-sizing rules.

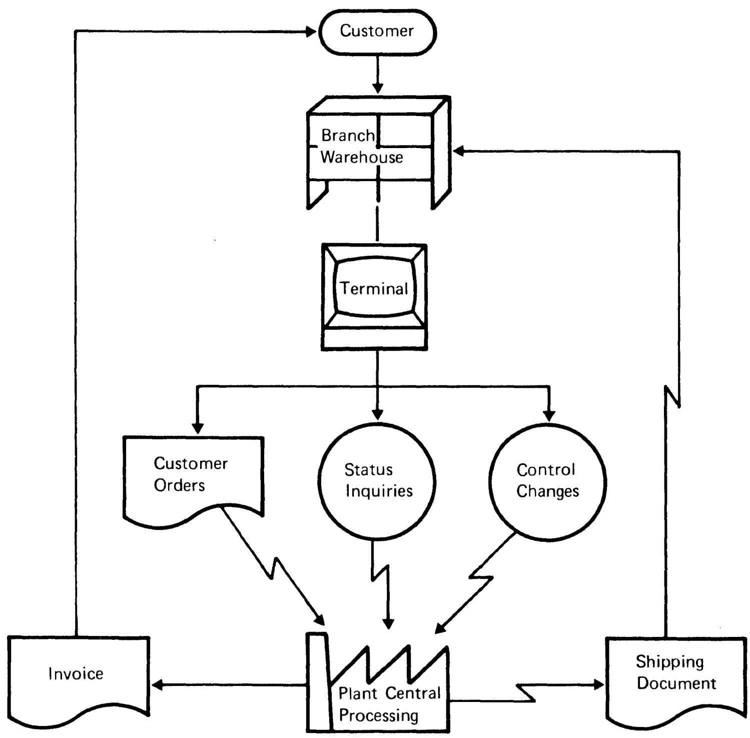


Figure 85. Terminals can greatly improve the level of service in a branch inventory control environment

INVENTORY MANAGEMENT represents a comprehensive system intended to serve as a model that is advanced both on the computer level and on the production and inventory control level. The selection of specific system features and techniques from among those described in this chapter will, of course, be up to the individual company. So will the actual use of the system. The management of a company that implements INVENTORY MANAGEMENT will have to decide on the types of output to be generated, and on the purposes and methods of their use.

The following is a brief review of system-use considerations that are of a fundamental nature and should be relevant to all implementations of INVENTORY MANAGEMENT.

Dampening the Effects of Change

INVENTORY MANAGEMENT is an online terminal-oriented system designed to be continuously up to date to the highest degree possible. As a consequence, it is very sensitive to changes in its environment, and functions in a continuous replanning mode. For example, MATERIAL REQUIREMENTS PLANNING always schedules the completion of a planned order to coincide with the earliest period where a net requirement appears. If requirements change, the date and/or quantity of the order may have to be altered.

Figure 86 shows how a small change in the requirements of a higher-level assembly can shift the planned order due date. This, in turn, causes a net change in the requirements for the next lower-level items.

Since the system is continuously updating itself, it is also replanning and thus revising previous orders. This might appear as a stream of constant revisions in orders going to the shop or to Purchasing. In other words, the system might appear overly “nervous”.

But a distinction should be drawn between the *system being informed,* up to the minute, and the *frequency of action* taken on the basis of the information. INVENTORY MANAGEMENT is designed to record all changes, however small, as quickly as possible. The frequency of action can, on the basis of practical considerations, be regulated independently of the rate of change within the system.

Period	1	2	3	4	5	6
Net Requirements	0	0	30	25	30	20
Planned Orders			55		50	
Net Change Requirements		+5	-5			
New Net Requirements		5	25	25	30	25
New Planned Orders		55 ←	•		50	
Net Change Requirements		+55	-55			

Figure 86. Small changes in the production schedule may force a series of lower-level net changes

The "nervousness" on the level of *planning* is a deliberate objective of INVENTORY MANAGEMENT, and represents a superior feature of the system. Any "nervousness" on the level of *reaction* can, and should, be dampened. The degree and frequency of reaction to change is affected by the following:

- Normal buffers within the system absorb some minor changes, precluding need for action.
- Programmed dampers limit the degree of reaction to changes in stock status.
- The timing of action can be regulated independently of the timing of change occurrence.

Normal system buffers

Reaction to changes in requirements (and therefore in stock status) is generally called for when requirements *increase,* or when the timing of planned performance *advances.* For the opposite type of change, a delay or lack of reaction can be tolerated.

Many minor changes of the type that would otherwise require action are, however, absorbed by inventory buffers that exist as a result of previous inventory management decisions. These buffers are created by safety stock, safety lead time, and temporary excesses in inventory due to lot sizing, engineering changes, reduced requirements, forecast error, overshipments, overruns, and premature deliveries by suppliers.

The system constantly strives to use up such temporarily excessive inventories as early as possible, through the net requirements planning process. Inventory excesses are thus automatically prevented from accumulating, but under normal conditions they exist, in some measure, at any point in time.

Safety stock is a planned buffer. It represents inventory set aside to absorb fluctuations in demand during replenishment lead time. In a situation where demand has exceeded requirements, safety stock can absorb these increased requirements, and a change to the released order, or to the planned order schedule, is not necessarily required. *Safety stock is considered available during replenishment lead time.* At the time of order receipt, or upon occurrence of a stockout, the planned order position is reevaluated and schedule alterations are made to cover the forecast and safety stock requirement. This may alter the planned order release dates.

Safety lead time has an effect similar to that of safety stock. For dependent demand items a safety lead time is sometimes allowed to absorb possible deviations from the specified delivery date. If a change in requirements causes an order due date to be shifted slightly forward, the system can use the lead time allowance to halt the explosion of such a change.

Order size often creates a temporary inventory excess, because many items are ordered in economical quantities. Excess availability caused by the economics of order size can be used to absorb net changes (Figure 87).

Period	1	2	3	4	5
On Hand	20				
Released Orders	300				
Planned Requirements	40	30	–	20	–
Planned Availability	280	250	250	230	230
Net Change (New Requirement)		+100			
Availability with Net Change	280	150	150	130	130

Figure 87. Temporary inventory excess resulting from economic lot-sizing considerations can absorb changes in requirements

Forecast error may create an inventory buffer. Forecasts are usually based on historical performance and may be modified by human judgment. If demand has been less than forecast, a future increase can be met by the available inventory. Forecasts are made not only of customer demand but also of miscellaneous demand and scrap.

As indicated in Figure 88, a change can be absorbed by the difference between expected and actual demand. In the example, because actual requirements were 15 less than expected, the change of plus 10 in period 1 can be accepted without a change to planned or released orders. Temporary inventory excesses caused by other factors, especially engineering changes, overruns, overshipments, and premature deliveries, as well as better-than-expected yields on orders for items subject to scrap, also act as buffers that tend to absorb minor changes in requirements.

Period	–2	–1	0	1	2	3
On Hand	40					
Released Orders					50	
Planned Requirements	10	10	10	10	15	10
Planned Availability	30	20	10	0	35	25
Actual Requirements	7	5	3			
Revised Availability	33	28	25	15	50	40
Net Change (New Requirement)				+ 10		
Availability with Net Change	33	28	25	5	40	30

Figure 88. Differences between planned and actual availability absorb changes in requirements

Programmed dampers

Despite built-in buffers to minor change, schedule alterations are still necessary. The longer the materials planning horizon, the more planned orders are subject to change. The buffers just discussed will absorb many changes in the near horizon and therefore released orders have to be revised less often. Further out in the planning horizon, however, planned orders will have to be altered to cover the change in requirements. Minor alterations to such orders can be prevented, if desired, through the use of change-dampening factors. The latter pertain to changes in *timing* and to changes in order *quantity*.

Many changes take the form of shifting an existing planned order a few days in either direction. To prevent having to explode small changes in the timing of planned orders, an *order timing damper* is employed. This is stated as a number of days on either side of the current date (X and Y in Figure 89) that will be absorbed before a change in the timing of a planned order is made.

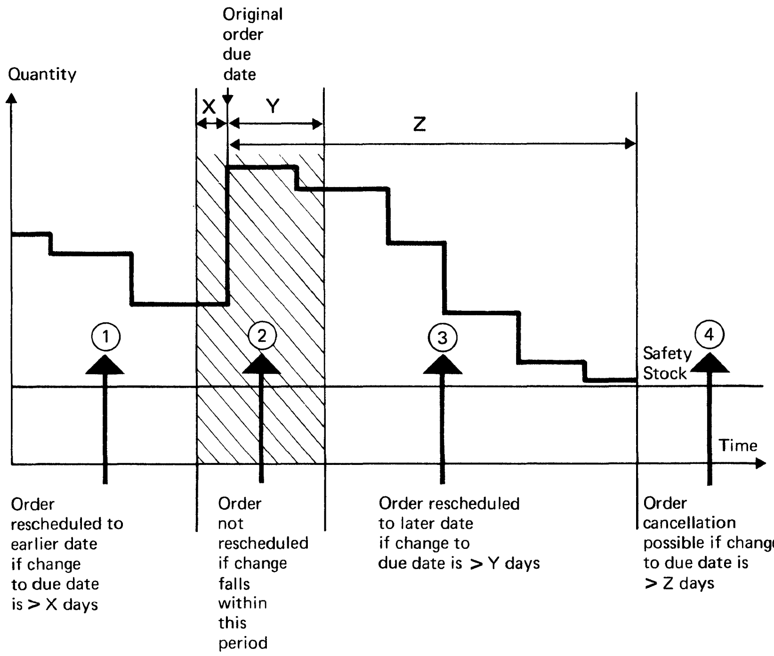


Figure 89. An order timing damper, stated as a series of factors, halts minor schedule changes

A third factor, Z in Figure 89, is used to measure major delays affecting only released orders. If there is a delay beyond an allowance of Z days, a notice of rescheduling or possible cancellation is generated in the inventory administrator's or buyer's Action File.

These factors may vary by item and will vary by the type of order; that is, a released order (particularly, a purchase order) should generally have tighter restrictions on change in timing than a planned order.

When lot sizes can vary depending on the net requirements schedule, as in the case of ordering discrete quantities, or when one of the lot sizing techniques is used, a *quantity change damper* can be employed. Items with fixed lot sizes do not require this damper.

The factors are applied in a manner similar to that of the order timing damper, that is, the minimum plus or minus quantity that will be acted upon by the system.

The factors will also vary by the type of order (planned or released) to which they apply. Quantity changes to released orders are very difficult to initiate. The shorter the elapsed time since order release, the better the chance of quantity alteration. Therefore, the factor applicable to open orders should be stated as a function of the number of days since release.

The timing of action

In a terminal-oriented system, changes can occur every minute of the day as a result of updating inventory, order, and requirements data. Stock status is not significantly affected by most of the updating transactions – for example, a planned component issue against a previously released order, or the allocation of available inventory to the customer order. Schedule reevaluation is, however, called for by some transactions, such as:

- Unscheduled stock issues
- Scrap in excess of the allowance
- Physical inventory adjustments (short counts)
- Miscellaneous demand exceeding forecast
- Entry of an engineering change

Management may not wish to commit resources to evaluating all possible *individual* changes as they occur. Furthermore, many changes may occur to the same item on the same day, in which case orders would have to be replanned several times that day, even though the changes may have a mutually canceling effect.

Human reaction to change can be *de-coupled* from the rate at which individual changes occur and are processed by the system. The most common method of dampening reaction to change is simply to *delay* such reaction. In practice, this takes the form of periodic planning or action cycles on the part of the inventory administrator. He does not react to the continuous stream of individual changes, but lets them accumulate for a period of, say, one day or longer.

The computer can be programmed to provide output of action requests on a cyclical basis. Some of these action messages may typically be generated, in a batch, once a day. Many requests for normal order action (release of shop orders and purchase requisitions. as well as rescheduling of open orders) belong in this category.

Different action cycles apply to various types of action, depending on its purpose. Thus due dates for all released shop orders may be reevaluated once per shift, so as to maintain the validity of shop priorities. A weekly cycle would be sufficient for certain types of action messages (items to be counted during the next week, for example).

Other types of messages should be generated without *any* delay, because corrective action time is critical. For example, a released purchase order may become a candidate for cancellation, as a result of changed requirements. A 24-hour delay in reacting to the new situation can make the difference between being and not being able to cancel. Other examples of situations that call for reaction without delay are excessive scrap, requirements falling into the past caused by a change in the status of a higher-level item, a significant downward adjustment of inventory following a physical count, etc.

When major changes in the master production schedule are being processed, or following regular periodic schedule revisions, all action-request output should be suppressed until the net change has been completely processed by MATERIAL REQUIREMENTS PLANNING. This type of change may affect thousands of records, and the status of an inventory item may change several times during the processing of such a change.

It should be kept in mind that planning cycles and action cycles are established on a more or less arbitrary basis. Delaying action on available information does dampen reaction to change, but delay obviously cannot be prolonged indefinitely. Under any action cycle, once delay is terminated, subsequent changes can still invalidate the action taken. As a general rule, it is better to act with less delay under a system capable of frequent – or continuous – replanning, reevaluation and revision of previous action, than to tolerate unresponsiveness by operating on long planning and action cycles.

INVENTORY MANAGEMENT offers a range of responses, from zero-delay to monthly or quarterly cycles. The relative promptness of reaction to change should be a function of the *type* of change in question.

Outputs and Their Use

INVENTORY MANAGEMENT acquires, organizes, processes, and maintains such a wealth of inventory-related data that the number of the various outputs possible is practically limitless. No attempt is being made to specify in this chapter what all of the outputs should be for a given company.

The types of output, their format and timing, and the medium on which they should be conveyed (printout, visual display, audio response, etc.) to the recipient, must be determined by management, so that the system can meet their particular needs.

Some typical outputs, and their use, have been discussed previously, at various points in this chapter – particularly, under "Role of the Inventory Administrator". Here, comment will be limited to principal output *categories,* as follows:

- Outputs for inventory control action
- Outputs for the planning of capacity requirements
- Outputs for control over shop priorities
- Outputs for keeping the master production schedule consistent with the materials plan
- Outputs for management control over performance

Inventory control action outputs

This is the category of the most commonly recognized types of output – those calling for inventory control action. Outputs in this category form the bulk of all the information on which the inventory administrator acts.

Here belong system-generated requests for new shop order releases, for purchase requisition releases, and for alteration of previously released order quantities, including order cancellations. Action on these types of output is generally routine.

Inventory control action is also involved in the case of requests for physical counts, as discussed previously under "Inventory Accounting" Expedite notices pertain primarily to released purchase orders. Shop orders are not expedited, in the conventional sense, under COPICS. Their relative priorities are changed by MANUFACTURING ACTIVITY PLANNING, based on revised order due dates generated by MATERIAL REQUIREMENTS PLANNING. The respective outputs are included in the category of shop priority control outputs.

Non-routine outputs in the inventory control category are listings of inactive or obsolete inventory items, intended to form the basis for inventory writeoff, and inventory investment projections discussed previously.

Capacity Requirements Planning outputs

The time-phasing feature of MATERIAL REQUIREMENTS PLANNING provides built-in information for the planning of capacity requirements. This is the statement of orders planned for future release, called the *planned order schedule*, which is developed (and maintained) by the system for each inventory item. This schedule extends over the planning horizon. After it is converted to machine loads and summarized by work center by time period, a highly accurate picture of productive capacity requirements is obtained.

This category of output is intended primarily as input to another system (that is, MANUFACTURING ACTIVITY PLANNING) rather than for direct use by a human recipient. A detailed discussion of how capacity requirements are determined, based on the planned order schedules, is included in *Chapter 6, Manufacturing Activity Planning.*

Shop priority control outputs

Because it develops net requirements on the basis of both on-hand inventory and released orders, MATERIAL REQUIREMENTS PLANNING possesses the inherent capability to reevaluate the *validity of due dates* on all released shop orders. This reevaluation is automatic in the process of netting requirements. The system operates in "net change" mode, that is, either in frequent, short planning cycles or continuously (see "Net Change Material Requirements Planning"), which means that both planned and released order due dates are being constantly reevaluated.

It is important that shop order priorities, to the extent that they are based on order due dates, be always determined from *currently valid* due dates. The system output indicating that a current "date of need" for a released shop order differs from the (previously established) order due date can be treated two ways.

If this type of output is directed to the inventory administrator for action, he evaluates the validity and significance of the reschedule request, as has been discussed previously under "Uses of Pegged Requirements". In most cases he will authorize a revised order due date that will subsequently be processed by MANUFACTURING ACTIVITY PLANNING.

The output, however, can bypass the inventory administrator and flow directly into MANUFACTURING ACTIVITY PLANNING. Shop order priorities are then automatically revised to conform to current order due dates, which, under this alternative, always equal the dates of need.

As the dynamic order priorities used by MANUFACTURING ACTIVITY PLANNING are being constantly recalculated, little is gained by preventing the order due date from being changed, even though the change may be slight and not significant. There is advantage in all order due dates being equivalent to dates of need, at any point in time.

There are no drawbacks to changing an order due date repeatedly while the order is in process, provided each change is valid, and provided the system is capable of handling a constant stream of change. COPICS is expressly designed to process changes on a continuous basis. Under COPICS, shop order priorities can be maintained valid, and controlled, automatically.

Master production schedule consistency outputs

The materials plan, which is defined as the sum total of all existing released and planned order action, tends at times to be at variance with the master production schedule on which it is based (see *Chapter 4, Master Production Schedule Planning*). This is caused by the occurrence of unforeseen events in the shop (excessive scrap, machine breakdown, etc.), by poor supplier performance, and sometimes by the contents of the master production schedule being unrealistic.

Whatever the reason for it, a lack of correspondence between the materials plan and the master production schedule will create unnecessary problems. Its principal effect is on shop order priorities, some of which become invalid and unrealistic as soon as the master production schedule reflects something other than what can actually be produced.

Because shop personnel very quickly learn that a high priority for a component of a product that cannot be built on schedule is false, they then begin to disregard the formal system-generated priorities, and the priority scheme, in effect, collapses. This is a common problem in many manufacturing companies. To avoid this problem, it is necessary to keep reconciling the master production schedule (what we would *like* to produce) with the current materials plan (what we will be ***able*** to produce). The need for this type of reconciliation has previously been discussed under "Pegged Requirements".

It is an important function of the inventory administrator to initiate alterations in the master production schedule, based on system outputs indicating that some part of the materials plan cannot be met. Pegged requirements provide the upward trace to the end items affected.

The respective end item schedules must then be revised accordingly. Once this is done, the net change to the master production schedule is automatically reprocessed by MATERIAL REQUIREMENTS PLANNING, which reestablishes valid order due dates (and thus shop order priorities) and brings the overall system into harmony.

The system is eminently capable of providing, at the right time, all the information required for reconciling the master production schedule with the materials plan. Failure to act on this information inevitably leads to shop confusion, expediting, misuse of available capacity, and increased manufacturing costs.

Another type of output included in this category results from using MATERIAL REQUIREMENTS PLANNING as a simulator. This has previously been discussed under "Trial-Fitting a Proposed Schedule Change". This type of output informs the inventory administrator, and management, about the *feasibility* of a proposed change to the master production schedule caused by the receipt of a customer order, by a forecast change, etc.

If customer orders (and their delivery dates) are entered into the system indiscriminately, delivery promises become unreliable and manufacturing activities are put under stress that results in disruption, confusion, and increased cost.

Use of the system for purposes of simulating the effects (availability of inventory, lead time, and productive capacity) of a given change in the master production schedule *before* such a change is actually put into effect, prevents the problems just mentioned from arising.

Performance control outputs

MATERIAL REQUIREMENTS PLANNING can provide management with information necessary for control over several types of performance essential to the successful execution of the overall manufacturing program. Timely performance is required from:

- Inventory administrator
- Buyer
- Supplier
- Factory

The system plans the performance of all of the above – the items and their quantities that the inventory administrator and buyer should order during the current period, what should be received from suppliers, and what should be completed by the shop during this period.

INVENTORY ACCOUNTING reports *actual* performance, through the processing of all inventory transactions and updating of the item records. MATERIAL REQUIREMENTS PLANNING, when it updates these records for the passage of time (at the end of each period), can compare actual vs *planned* performance for the period just passed, and can report the exceptions.

The system has the inherent capability to determine, item by item, what should have taken place but did not, as well as what has taken place that should not have. The resulting output is a management report highlighting deviations from planned performance.

The system can report overorders, underorders, or failure to order, by inventory administrator and buyer; overshipment, undershipment, overdue delivery, and premature delivery by suppliers; and, of course, behind-schedule performance and partial order completions by the shop. The system can pinpoint deviations from planned performance to the individual inventory administrator, buyer, supplier, or factory department.

The system thus not only generates the materials plan but monitors its execution. Complete and timely information on which to take inventory action, as well as information about such action, is provided by INVENTORY MANAGEMENT.

Summary

INVENTORY MANAGEMENT is one of the keystones of successful production planning. If it is not performed correctly, all other planning is much less effective than it should be.

There are two basic aspects of INVENTORY MANAGEMENT:

- INVENTORY ACCOUNTING
- INVENTORY PLANNING AND CONTROL

INVENTORY ACCOUNTING is concerned with maintaining accurate inventory records. Unless this is done, INVENTORY PLANNING AND CONTROL is ineffectual. Accounting consists of maintaining a correct available inventory balance. This includes not only transaction processing, but also the establishment of proper transaction editing procedures, error control, and audit trails. Physical inventory counting is a monitor that helps make sure the system is performing correctly.

INVENTORY PLANNING AND CONTROL determines the size and schedule of replenishment orders. In doing so, it establishes a planned inventory level and stockout percentage, called a *service level.*

The approach to INVENTORY PLANNING AND CONTROL depends upon the type of demand. If the techniques are misapplied, excessive inventory and stockout will occur.

Independent demand for finished products is forecast and developed into a master production schedule reflecting the way production actually plans to manufacture. Safety stock is established to absorb errors in the demand forecast.

On the basis of the master production schedule and bills of material, the *dependent* requirements for subassemblies, components, and raw material are developed. *Safety stock* is not required for these items; rather, timing delivery of the planned order is the most important consideration. Unlike independent demand, the system schedules delivery to try to achieve a 100% service level. This is very important for assembly shop orders where all components must be available before production can start.

Changes to the production plan, from the finished product level to the raw materials level, are made on a *net change* basis. This mean that the impact of significant changes, or deviations from plan, ca be determined quickly. Waiting for a weekly or monthly planning cycle is eliminated. *Net change* also allows the impact of significant changes to the master production schedule to be determined in advance. In addition, it significantly reduces the planning cycle in interrelated multiplant situations.

The system allows management to actually control the level of inventory and know in advance what the impact of changes in decisions or rules will be on costs, customer service, and inventory levels. The system ensures the minimum inventory investment consistent with management objectives.

Notes

Notes

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